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ANALYSIS OF THE DEVONIAN SHALES IN THE APPALACHIAN BASIN

Volume 2: Appendices

September 1982

Work Performed Under Contract No. AC21-80MC14693

For
Morgantown Energy Technology Center
Morgantown, West Virginia

Cliffs Minerals, Inc.
Granville, West Virginia

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ANALYSIS OF THE DEVONIAN SHALES IN THE APPALACHIAN BASIN

VOLUME II

(APPENDICES)

SEPTEMBER 1982

CONTRACT NO. DE-AC21-80MC14693

CLIFFS MINERALS, INC.
GRANVILLE, WEST VIRGINIA 26534

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INTRODUCTION TO APPENDICES

Thirty-three wells were core drilled from 1975 through 1981 for the Eastern Gas Shales Project in the Appalachian Basin. The following appendices are a compilation by well of all the fracture data, mechanical characterization tests, stratigraphic projections, geologic structural interpretations, and gas production information available through the Unconventional Gas Resources Library at DOE/METC, Morgantown, West Virginia.

The fracture analysis data for the first well, EGSP-West Virginia #1, was taken from the DOE files. The fracture analyses of the next eight wells that were drilled were taken from a Master's Thesis by Mr. Mark Evans entitled, "Fractures In Oriented Devonian Shale Cores From The Appalachian Basin," Volume II, 1980. These wells include EGSP-Kentucky #1, Kentucky #3, Ohio #1, Ohio #2, Virginia #1, West Virginia #2, West Virginia #3, and West Virginia #4. Data and descriptions from his work are asterisked (*) in the appendices and footnoted as to the pages referenced, with some material edited to include more recent information. The remaining twenty-four wells were analyzed by Cliffs Minerals, Inc. and the data summarized in these appendices were taken from the Phase I and Phase II Reports on the individual wells.

Mechanical characterization tests were collected from a variety of sources. The early wells drilled were tested by the staff at MERC and include EGSP-Kentucky #1, Kentucky #3, Ohio #1, Ohio #2, West Virginia #1, West Virginia #2, West Virginia #4, Dr. S. Peng at West Virginia University tested West Virginia #3, and Dr. K. Kim at Michigan Technolog-

ical University tested West Virginia #5. The remaining wells were tested at Michigan Technological University's Rock Mechanics Laboratory under the supervision of Dr. William Gregg. The work at MTU was subcontracted by Cliffs Minerals, Inc. and results are published in the Phase III Reports on each well.

Geologic structural interpretations and stratigraphic projections were compiled from maps generated by the state geological surveys under EGSP contracts and the U.S.G.S. which coordinated the mapping efforts.

Production data were collected mainly from the publication DOE/METC #145, "Comparative Analysis of Stimulations in the Eastern Gas Shales" compiled by A. I. Horton, 1981, and through personal communication with DOE personnel involved with the program. Gas shows drafted on some of the well summary charts were taken from Cliffs Minerals, Inc. Phase I Reports.

The well summary charts that are located as the last figure for each well description contain the detailed fracture distributions and mechanical test results for the stratigraphic members cored. The stratigraphic sections and nomenclature were developed by comparison of the geophysical logs for each well with sections published by the U.S.G.S. in METC/EGSP Series 1400 Map and the OC-80 Series Charts, 1980.

The gamma ray log and density log are reproduced on each chart to show the correlation to stratigraphic members of the Devonian Shale sequence. A large quantity of data was collected in the early stages of the program to define the relationship of radioactivity to the individual shale members. The relationship serves as a useful tool in correlating

the radioactive organic shales across the entire Appalachian Basin. Temperature and noise logs were included, when they were available, to show zones of gas emanation in the well bore.

The cored-interval column defines the sections of the well from which oriented core was retrieved for analysis. The natural fracture columns include the distribution of joints, faults and slickensides on the fault planes for each stratigraphic member plus a summation at the bottom. The rose diagrams used to display the information have the total number of fractures measured in the lower right. The percentage in the upper right indicates the value of the outer ring on the diagram. Each diagram represents the percentage of fractures measured in ten-degree increments from north.

The mechanical test results columns include pretest fractures in the samples, maximum ultrasonic velocity directions, orientation of cracks from point load tests, weakest tensile strength directions from directional tests, and crack orientations from hydrofracture tests when available.

All of this information has also been plotted by stratigraphic member and summarized at the bottom of each column for comparison with the other physical properties of the shales.

FIGURE 1 WELL LOCATIONS MAP

TABLE 1

LISTING OF APPALACHIAN BASIN EGSP WELLS

EGSP WELL NO.	COMPANY WELL NO.	STATE WELL NO. (IF ANY)	LOCATION (COUNTY)	LATITUDE	LONGITUDE	YEAR CORED	CONTRACTOR	CORED INTERVAL (FT.)	AMT OF CORE (FT.)	TOTAL DEPTH (FT.)	ELEVATION ABOVE SEALEVEL (FT.) GL	KB
KY #1	Nicholas Combs # 7239	28982	Perry	37°21'01"	83°10'30"	1975	KY-WV Gas Co.	2369-3690	339	3734	1080	1090
KY #3	20336	Permit # 3120	Martin	37°46'33"	82°29'21"	1976	Columbia Gas Company	2429-3411	982	3456	934	944
KY #4	3-RS	33985	Johnson	37°57'40"	82°56'20"	1978	Ashland Exploration	967-1510	510	1510	936.4	973
NY #1	6213	Permit # 00095	Allegany	42°20'56"	77°49'08"	1978	NY State Natural Gas	370- 546 963-1022 1321-2358 2486-2665 2723-2926	1551.2	3232	1839.7	1850
NY #2			Allegany	7300'S 42°10'	2250'W 77°47'30"	1980	Joyce Management	NONE			2025	
NY #3	Scudder #1	Permit # 00602	Steuben	42°11'26"	77°04'59"	1980	Donohue, Anstey & Morrill	1203-2163	60.2	1342	1503	
NY #4	Valley Vista View #1	Permit # 00583	Steuben	42°09'50"	77°21'13"	1980	Donahue, Anstey & Morrill	3010-3082 3790-3848	132.5	3848	1451	1464

TABLE 1

LISTING OF APPALACHIAN BASIN EGSP WELLS
PAGE 2

EGSP WELL NO.	COMPANY WELL NO.	STATE WELL NO. (IF ANY)	LOCATION (COUNTY)	LATITUDE	LONGITUDE	YEAR CORED	CONTRACTOR	CORED INTERVAL (FT.)	AMT OF CORE (FT.)	TOTAL DEPTH (FT.)	ELEVATION ABOVE SEALEVEL (FT.) GL	KB
OH #1	Glen Gery #5-745	Permit # 835	Carroll	40°37'33"	81°17'54"	1974	Canton Oil & Gas Company	2080-2200 3080-3200	240	5187	1039	1045
OH #2	R-109	Permit # 3521	Washington	8400'S 39°25'00"	6200'W 81°32'30"	1976	River Gas Co.	3490-3714	224	6262	816	828
OH #3	Louise Beckholt #1		Knox	40°23'53"	82°30'10"	1979	Thurlow Weed & Association		679.8	1260	990	NA
OH #4		Wildcat	Ashtabula	6500'S 41°57'30"	2900'W 80°32'30"	1979	Monsanto Research/ U.S. Steel	509- 567 746- 876 949- 989 1069-1109 1119-1209 1309-1385	435.2	1400	583	NA
OH #5	20149-T	Permit # 1100	Lorain	41°13'34"	82°1'34"	1979	Columbia Gas	400-1280	880.7	1340	878	888
OH #6-1	#1-5	Permit # 482	Gallia	38°45'07"	82°21'58"	1979	Mitchell Energy	1810-1866 2311-2369 2446-2502	169.8	2845	748	759
OH #6-2	#1-7	Permit # 479	Gallia	38°44'44"	82°23'05"	1979	Mitchell Energy	1697-1755 2282-2340 2418-2476	175.5	2770	734	745

TABLE 1

LISTING OF APPALACHIAN BASIN EGSP WELLS
PAGE 3

EGSP WELL NO.	COMPANY WELL NO.	STATE WELL NO. (IF ANY)	LOCATION (COUNTY)	LATITUDE	LONGITUDE	YEAR CORED	CONTRACTOR	CORED INTERVAL (FT.)	AMT OF CORE (FT.)	TOTAL DEPTH (FT.)	ELEVATION ABOVE SEALEVEL (FT.) GL	KB
OH #6-3	#1-6	Permit # 474	Gallia	38°43'57"	82°21'28"	1979	Mitchell Energy	1988-2046 2590-2602	69.7	3070	936	947
OH #6-4	#1-8	Permit # 477	Gallia	38°44'24"	82°20'47"	1979	Mitchell Energy	1842-2775.5	933.3	3062	910	922
OH #6-5	#1-9	Permit # 478	Gallia	38°44'14"	82°22'54"	1979	Mitchell Energy	1660-1717 1940-1998.7 2440-2498	174.8	2720	658	669
OH #7	20143-T		Trumbull	7200'S 41°10'00"	1300'E 80°55'00"	1979	Columbia Gas	1500-2710	1210.4	2756	951	962
OH #8	Shockling #1		Noble	39°42'49"	81°27'42"	1980	Donahue, Anstey & Morrill	1750-2086 3085-4152	1346	4226	860	874
OH #9	10056A		Meigs	39°4'19"	81°50'18"	1981	DOE/SAI/Gruy	2914-3372	458	3450	755	737
PA #1	M.R. Explora-tion #1	MCK	McKean	2900'S 41°52'30"	1100'E 78°37'30"	1979	Minard Run Oil Company	3470-3528 4530-5213	736.3	5295	2260	2271
PA #2	CEPS #1	All-20980	Allegheny	40°11'30"	79°53'30"	1979	CE Power Systems Combustion Eng.	6950-7505	542.9	7505	759	769

TABLE 1

LISTING OF APPALACHIAN BASIN EGSP WELLS
PAGE 4

EGSP WELL NO.	COMPANY WELL NO.	STATE WELL NO. (IF ANY)	LOCATION (COUNTY)	LATITUDE	LONGITUDE	YEAR CORED	CONTRACTOR	CORED INTERVAL (FT.)	AMT OF CORE (FT.)	TOTAL DEPTH (FT.)	ELEVATION ABOVE SEALEVEL (FT.) GL	KB
PA #3	State Park #1	ER1-20846	Erie	48305 42°10'00"	530W 80°07'37"	1979	Monsanto Research/ PA DER	375- 425 540- 660 720- 760 931-1051 1177-1275	392.4	1276	574	578
PA #4	McCall #5	Ind. 25073	Indiana	40°34'45"	79°11'15"	1979	Gruy Federal	7098-8012	892.8	8012	1523	1535
PA #5	Farm #1	Permit # 20022	Lawrence	41°5'34"	80°17'05"	1979	Peoples Gas Co.	3520-4126	586.5	4203	1081	1064
TN #1	DOE #1		Clairbourn	36°28'16"	83°25'45"	1978	TN Geol. Survey		245	254	1100	
TN #2	DOE #2		Clairbourn	36°28'03"	83°25'50"	1978	TN Geol. Survey		106	115.6	1120	
TN #3	DOE #3		Hancock	36°33'51"	87°9'19"	1978	TN Geol. Survey		751	755.6	1230	
TN #4	DOE #4		Hawkins	36°26'59"	83°5'43"	1978	TN Geol. Survey		1516	1525.1	1245	
TN #5	DOE #5		Hawkins	36°26'35"	83°05'33"	1978	TN Geol. Survey		200	275	1350	
TN #6	DOE #6		Hawkins	36°14'37"	83°37'22"	1978	TN Geol. Survey		650	486	970	

TABLE 1

LISTING OF APPALACHIAN BASIN EGSP WELLS
PAGE 5

EGSP WELL NO.	COMPANY WELL NO.	STATE WELL NO. (IF ANY)	LOCATION (COUNTY)	LATITUDE	LONGITUDE	YEAR CORED	CONTRACTOR	CORED INTERVAL (FT.)	AMT OF CORE (FT.)	TOTAL DEPTH (FT.)	ELEVATION ABOVE SEALEVEL (FT.) GL	KB
TN #7	DOE #7		Hawkins	36°18'55"	83°27'59"	1978	TN Geol. Survey		750	1294	1130	
TN #8	DOE #8		Hawkins			1979	TN Geol. Survey			915.6	NA	
TN #9	GFI #1	Permit # 124	Grainger	36°18'56"	83°24'33"	1980	Gruy Federal	1167-1219 1610-1739 1820-1865	226	1920	1140	1150
VA #1	20338	Permit # 253	Wise	37°00'37"	81°42'14"	1977	Columbia Gas	4870-4985 5210-5475	380	5741	2395.5	2405.5
WV #1	11940	Jac 1369	Jackson	1690'S 38°50'00"	11510'W 81°50'00"	1975	Consolidated Gas Supply	3410-3500 3600-3797	287	3935	835	846
WV #2	12041	Jac 1371	Jackson	15681'S 38°55'00"	4066'W 81°50'00"	1975	Consolidated Gas Supply	3220-3690	470	3744	662	673
WV #3	20403	Linc 1637	Lincoln	23760'S 38°10'00"	16368'W 82°10'00"	1976	Columbia Gas Corporation	2720-4028	1308	4065	1190	1202
WV #4	20402	Linc 1636	Lincoln	25502'S 38°10'00"	20803'W 82°10'00"	1976	Columbia Gas Corporation	2654-2720 3000-3118 3290-3588 3886-3968	614	3983	1153	1163

TABLE 1

LISTING OF APPALACHIAN BASIN EGSP WELLS
PAGE 6

EGSP WELL NO.	COMPANY WELL NO.	STATE WELL NO. (IF ANY)	LOCATION (COUNTY)	LATITUDE	LONGITUDE	YEAR CORED	CONTRACTOR	CORED INTERVAL (FT.)	AMT OF CORE (FT.)	TOTAL DEPTH (FT.)	ELEVATION ABOVE SEALEVEL (FT.) GL	KB
WV #5	D/K #3	MAS-146	Mason	38°55'30"	82°03'45"	1977	Reel Energy Incorporated	2673-3420	648	3420	665	675
WV #6	MERC-1		Monongalia	39°40'14"	79°58'44"	1978	DOE	7168-7509	350	7520	959	973
WV #7	Emch, Pyles Unit #1	WET-645	Wetzel	39°40'37"	80°49'26"	1978	Mobay Chemical	6100-6650	533.5	7007	1348	1355

APPENDIX A

KENTUCKY EGSP WELLS

KENTUCKY #1: (NICHOLAS COMBS #7239) WELL
KENTUCKY #3: (COLUMBIA GAS #20336) WELL
KENTUCKY #4: (SKAGGS KELLY UNIT #3RS) WELL

EGSP-KENTUCKY #1 (NICHOLAS COMBS #7239) WELL

LOCATION*[1]

The EGSP-Kentucky #1 well is located in Perry County, Kentucky, twelve miles due north of the town of Hazard (Figures 1, 1A and Table 1).

GEOLOGY

The well site is between the Pine Mountain Thrust Fault to the south and the Irving-Paint Creek Fault to the north. Regional structure of the Devonian Shales shows a monoclinal dip of less than 1° to the southeast. Structures on the base of the Three Lick Bed and the Lower Huron Shale show a distinct change in strike and dip of the contacts in the well site area (Figures 1B and 1C). Overall, the dip is S-SE toward the Pine Mountain Thrust Fault at the Kentucky-Virginia state lines. Just east of the well site the structure maps indicate a synclinal flexure which may be fault controlled in the basement rocks. A total of 339' of the Devonian was cored, from 2,369' to 2,708'. In this study, only two sections of the core were analyzed; a 52-foot section from 2,374' to 2,426', and a 71-foot section from 2,588' to 2,660' (Figure 1F). These sections comprised the only reliable core data available to the author. Within each of these two sections is a small interval with no fracture data.

PRODUCTION DATA*[2]

Five intervals of the Kentucky #1 well were stimulated by foam fracturing. After stimulation, interval 2,326'-2,675' had an initial open flow of 60 mcf/day, intervals 3,174'-3,180' and 3,412'-3,491'

combined had an initial open flow of 450 mcf/day, and intervals 2,560'-2,580' and 2,730'-2,790' combined had an initial open flow of 103 mcf/day (Komar, Frohne and Yost, 1978).

UNDIFFERENTIATED FRACTURES*[3]

The fractures in the two sections studied were previously logged and analyzed, and the results presented by Kulander, Dean, and Barton (1977). No natural fractures were logged by Kulander, et al., (1977), but they stated that there is a "remote possibility" that some of the fractures they classified as coring induced are actually pre-core (natural) fractures. The author is therefore placing all coring-induced fractures as logged by Kulander, et al., (1977) in the category of undifferentiated fractures. Kulander, et al., (1977), however, did differentiate slickensided fractures and horizontal mineral-filled fractures.

Undifferentiated fractures were found distributed throughout the sections studied (Figure 1F). The composite rose diagram of undifferentiated fracture strikes (Figure 1F) has four peaks. There is a 5.0% chance that the peaks at N05°-15°W and N03°E do not exist, and a 10.0% chance that the peaks at N37°W and N33°E do not exist. Undifferentiated fracture orientations show significant changes with depth (Figure 1F). Dominant orientations swing from N33°E in the Cleveland Member to N05°-15°W at the base of the Middle Huron Member and the top of the Lower Huron Member, back to N33°E in interval 2,614'-2,638' and then to N37°W in interval 2,639'-2,669'. The various fracture sets and their preference for certain intervals of the core may be the result of the interaction of several stress fields: tensile stresses associated with faulting in

the area, southern Appalachian tectonic compressive stresses, and the general east to northeast trending maximum compressive stress present in most of eastern North America (Sbar and Sykes, 1973).

FAULTS AND SLICKENSIDES*[4]

Faults are found in both sections of the core studied (Figure 1F), and most are subhorizontal to horizontal. The only inclined faults occur in the Lower Huron Member. The composite rose diagram (Figure 1D) has a single peak at N03°E. There is a 1.0% chance that this peak does not exist. The equal area projection of poles to fault plane surfaces has two clusters; one dipping 0°, corresponding to the numerous horizontal faults; and one dipping 60°W corresponding to the inclined N03°W striking faults.

The composite rose diagram of slickensides (Figure 1E) has four significant peaks. There is a 1.0% chance that the peaks at N87°W, N27°E, and N83°E do not exist, and a 5.0% chance that the peak at N33°W does not exist. The equal area projection of slickensides has several peripheral clusters corresponding to the horizontal slickensides, and a cluster dipping 60°W, corresponding to the slickensides on the N03°E striking faults. The N33°W set occurs primarily in the Cleveland Member, and the N87°W and N83°E sets occur primarily in the Lower Huron Member.

Tectonic compressive stress directed from the southeast may be responsible for the N33°W trending slickensides. The N27°E, N83°E, and N87°W sets may be related directly to local fault movement, or to compaction and settling of the rock after fault movement. The N83°E trending, 60°W dipping slickensides may indicate the presence of a north-south

trending normal fault to the west. Some of the scatter in slickenside orientation may be due to local movements on the flanks of low-amplitude, short-wavelength, discontinuous shale folds (Kulander, et al., 1977).

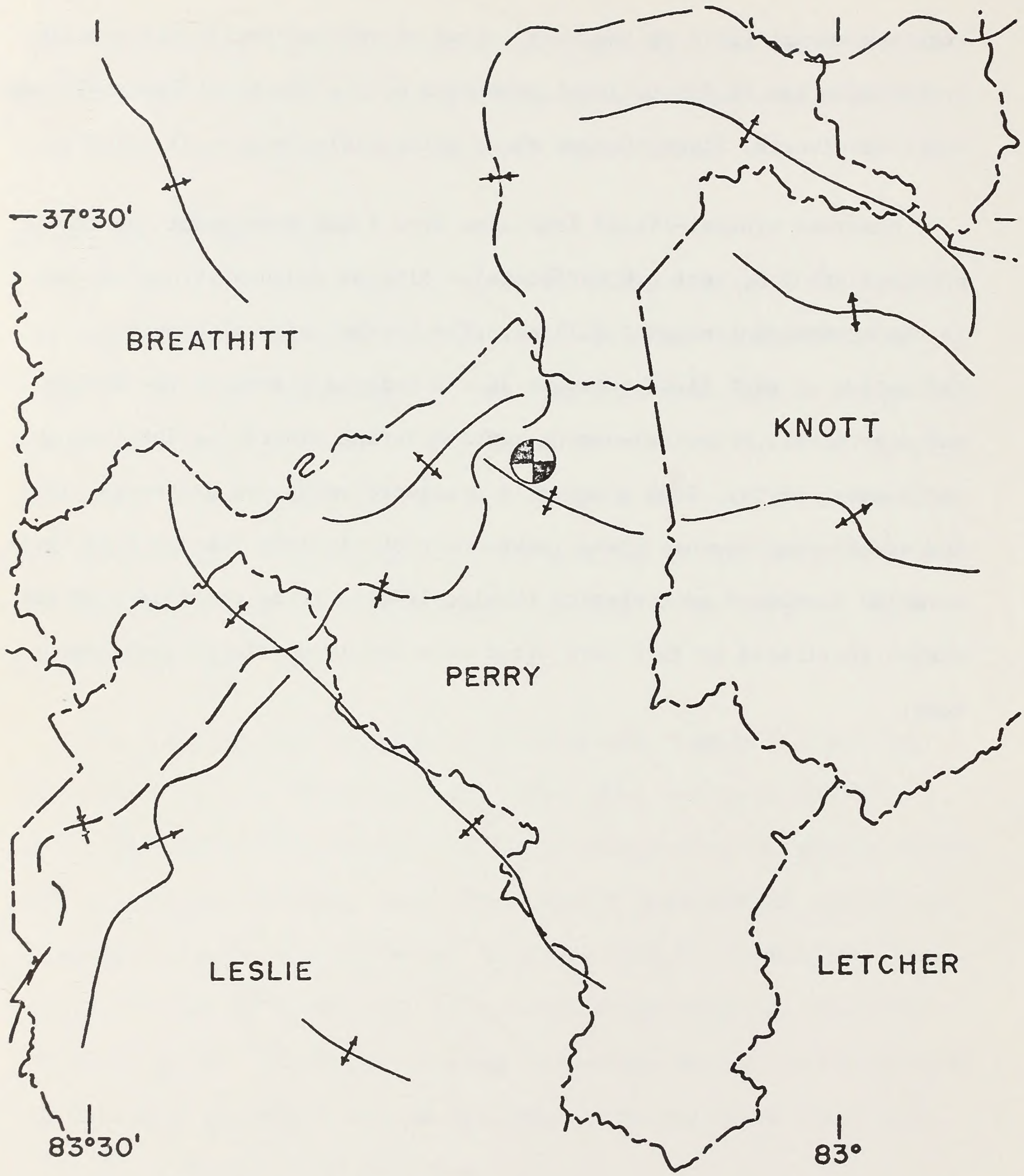
Numerous mineral-filled fractures were found throughout the two sections studied; most are horizontal. Fibrous and nonfibrous calcite is the predominant mineral filling. The fibrous mineral growth is indicative of high fluid pressure in the bedding planes of the shales and a vertical, principal-acting tension during mineralization (Durney and Ramsay, 1973). Such abnormally pressured rocks are preferred sites for décollement because these rocks are probably less viscous than their normally pressured counterparts (Kehle, 1970). It is possible that the shales penetrated by this core acted as a poorly developed décollement zone.

*[1] p. 229

*[2] p. 229

*[3] p. 229

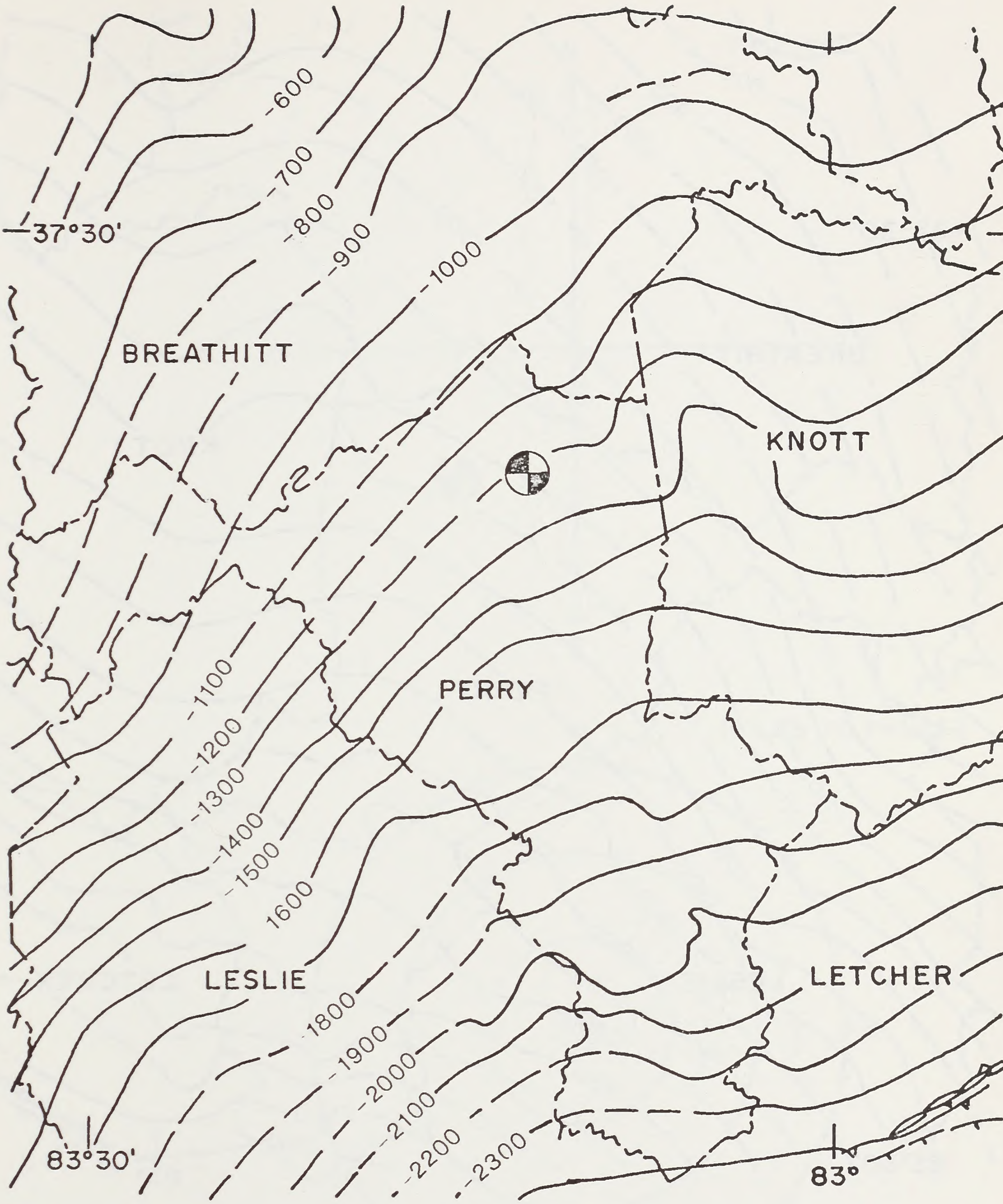
*[4] p. 231.



E.G.S.P. KENTUCKY - 1
SURFACE GEOLOGY
SCALE 1:370,000

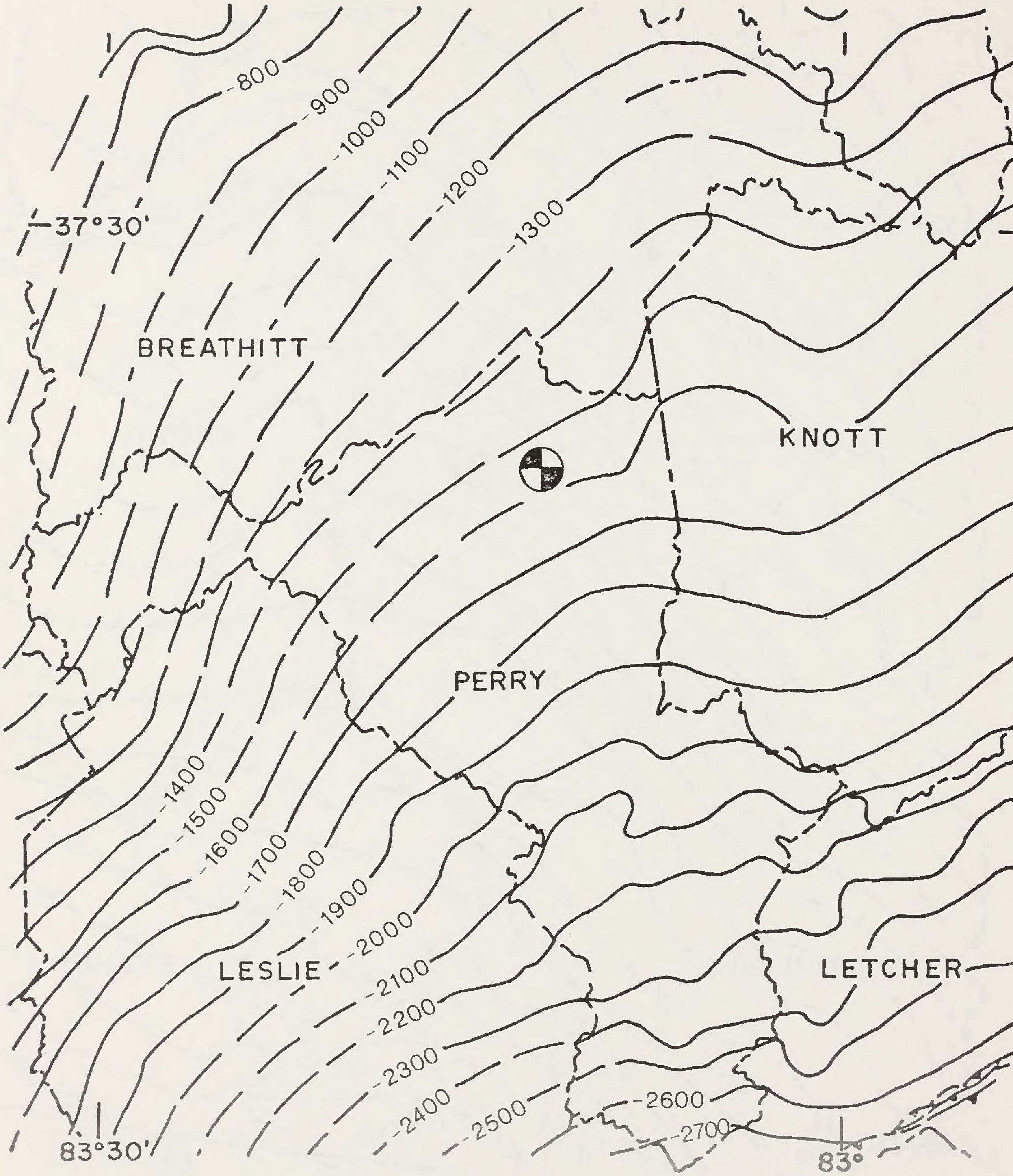
LEGEND: ANTICLINE
SYNCLINE

FIGURE 1A

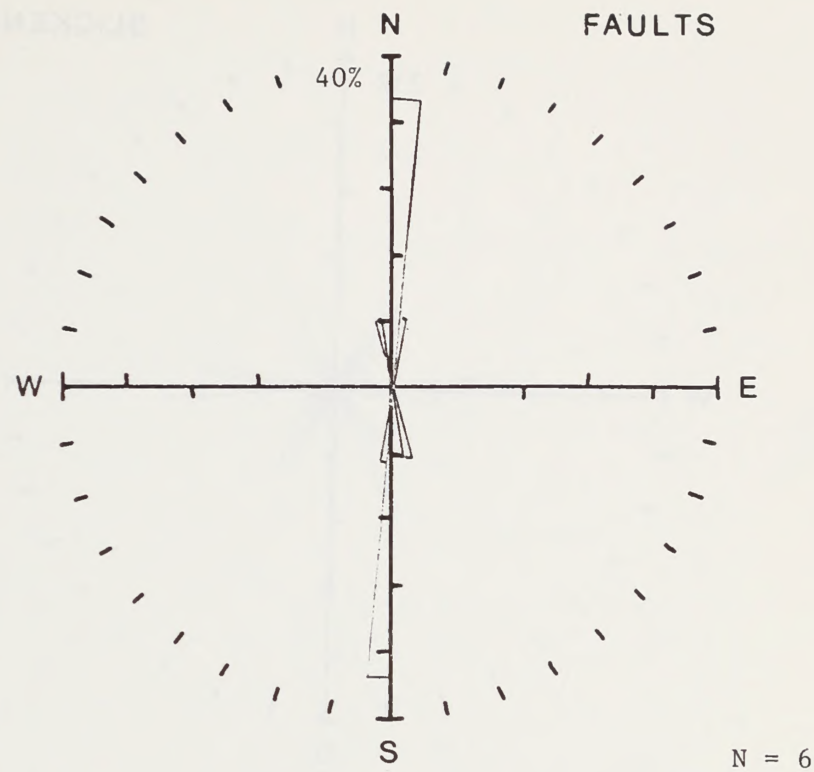


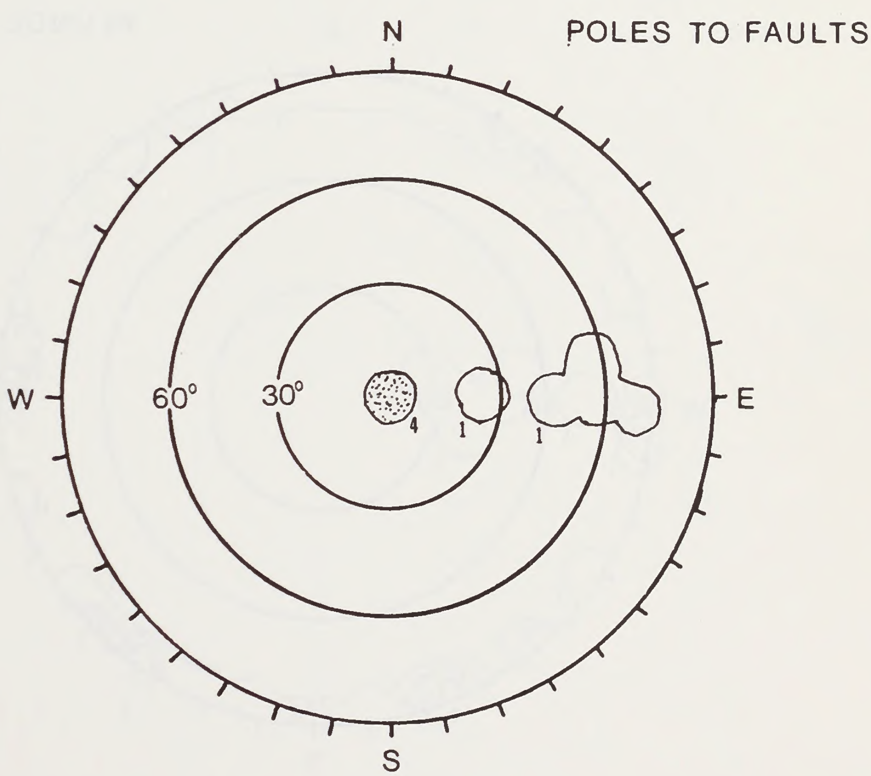
E.G.S.P. KENTUCKY-1
STRUCTURAL CONTOURS
BASE OF CLEVELAND
SCALE 1:370,000

FIGURE 1B



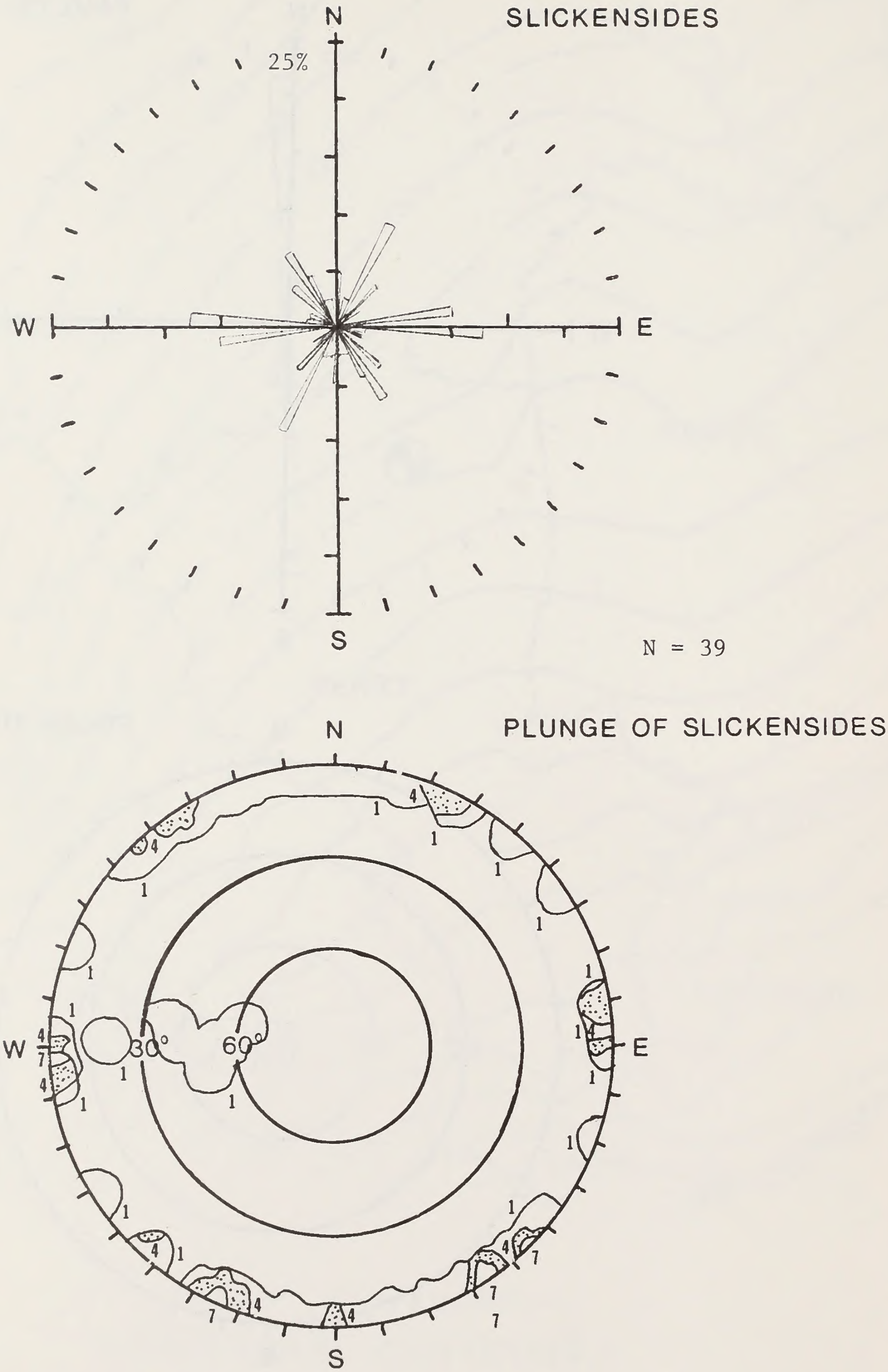
E.G.S.P. KENTUCKY-1
STRUCTURAL CONTOURS
BASE OF LOWER HURON
SCALE 1:370,000
FIGURE 1C





EGSP-KENTUCKY #1

Figure 1D. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.



EGSP-KENTUCKY #1

Figure 1E. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.

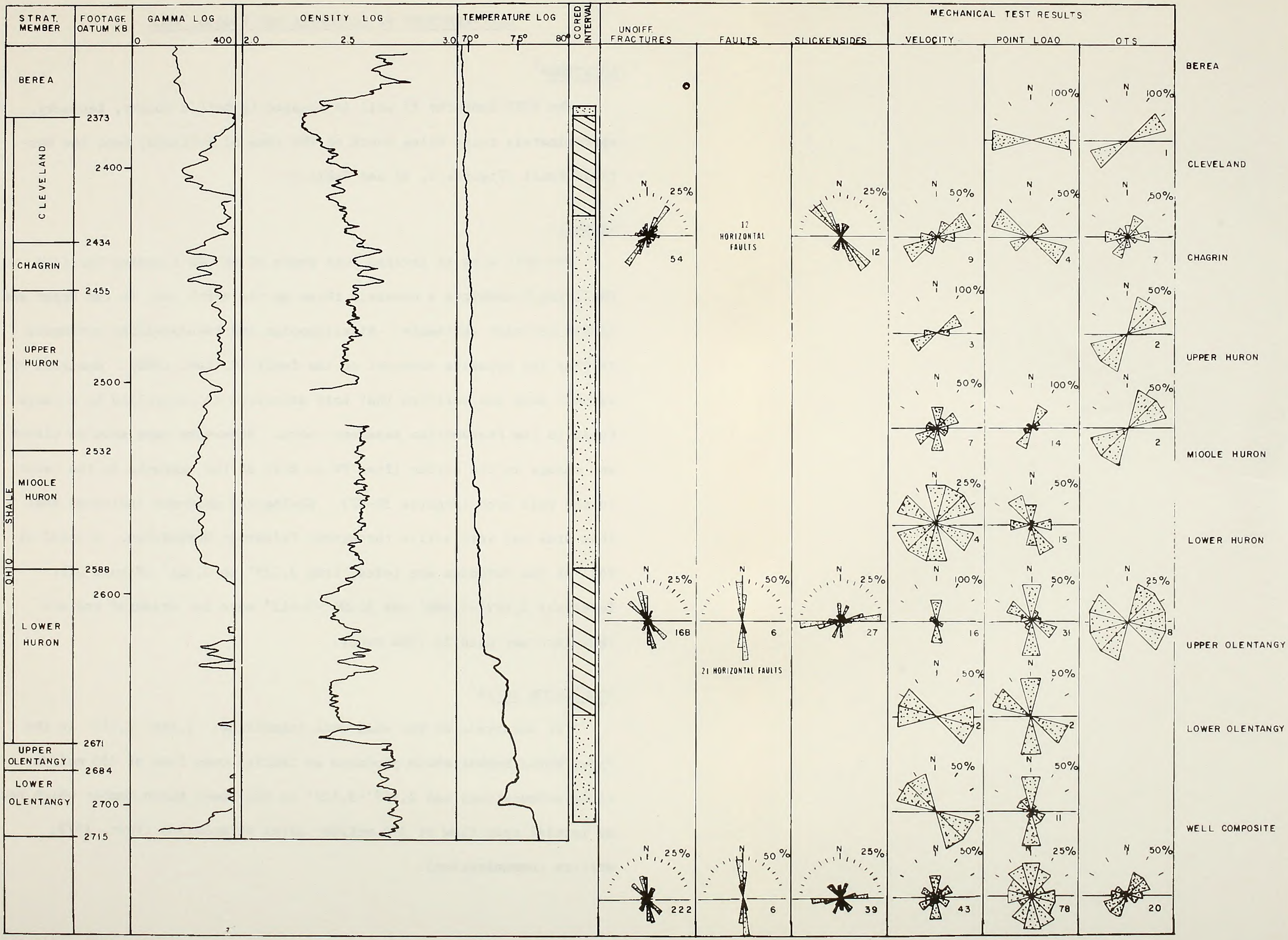


FIGURE 11 EGSP KENTUCKY 1 WELL SUMMARY

NOTE
FRACTURE INFORMATION TAKEN FROM X-HATCHED CORE SECTIONS.

CLIFFS MINERALS INC.

EGSP-KENTUCKY #3 (COLUMBIA GAS #20336) WELL

LOCATION*[1]

The EGSP-Kentucky #3 well is located in Martin County, Kentucky, approximately three miles south of the town of Warfield, near the Warfield Fault (Figures 1, 3A and Table 1).

GEOLOGY

The well site is located just south of the NE trending Warfield Fault which displays a downward throw on the north side in the Upper and Middle Devonian sediments. Mississippian and Pennsylvanian sediments display the opposite movement on the fault (K. Lee, 1980). Analysis of seismic data has verified that this structure is controlled by a large fault in the Precambrian Basement rocks. Structure maps show an offset and change in the strike (from NE to E-W) of the contacts at the fault in the well area (Figures 3B-3F). Geological evidence indicates that this area was very active throughout Paleozoic deposition. A total of 982' of the Devonian was cored, from 2,429' to 3,411' (Figure 3I). Intervals 2,429'-2,486' and 3,404'-3,411' were not oriented and are therefore not used in this study.

PRODUCTION DATA*[2]

Two intervals of the well were stimulated: 2,666'-2,712' in the Upper Huron Member which produced an initial open flow of 250 mcf/day after stimulation; and 2,968'-3,122' in the Lower Huron Member which had an initial open flow of 370 mcf/day after stimulation (Yost, 1979, written communication).

CORING-INDUCED FRACTURES*[3]

Coring-induced fractures are the most common fracture type in the core and are well distributed throughout the section (Figure 3I). The composite rose diagram of coring induced fractures has three peaks. There is a 1.0% chance that the peaks at N40°-55°E, N63°E, and N33°E do not exist. Most of the scatter occurs in the interval 2,487'-2,550'. In general, downhole fracture orientations gradually swing to the north.

The N33°E and N63°E fracture sets parallel the coring-induced fractures in the West Virginia #4 (#20402) and West Virginia #3 (#20403) cores, respectively, which are located to the northeast. The largest peak, N40°-55°E, bisects the two smaller peaks and probably represents merging of the two trends. The consistent coring induced fracture orientations suggest the presence of a stress or rock fabric anisotropy, which may be related to the general east to northeast trending maximum compressive stress present in most of eastern North America (Sbar and Sykes, 1973).

NATURAL FRACTURES*[4]

Natural fractures are found throughout the core (Figure 3I). The composite rose diagram of natural fractures shows wide variability in natural fracture orientations. No statistically significant peaks appear. However, three dominant trends are present: N67°W, N47°W, and N37°E. Natural fractures generally strike northeast in and above the Middle Huron Member and northwest below.

The N37°E natural fracture set parallels the N33°E coring induced fracture set and may be related to the same stress or rock fabric

anisotropy responsible for the coring-induced fractures. The two northwest striking natural fracture sets show no relationship to any known nearby structures. However, the wide variation in fracture orientation may be the result of interaction of stress fields associated with nearby faulting.

FAULTS AND SLICKENSIDES*[5]

Faults are found in and below the Middle Huron Member with most occurring in the West Falls Formation (Figure 3I). The composite rose diagram of faults (Figure 3G) has three peaks. There is a 5.0% chance that the peaks at N17°W, N47°E, and N83°E do not exist. The equal area projection of poles to fault plane surfaces has several clusters: one dipping 25°SW corresponds to the N17°W set; two clusters dipping 40°SE and 60°SE correspond to the N83°E set; and one dipping 30°SE corresponds to the N47°E set. The N83°E set occurs only in the Lower Huron Member and below, whereas the other two sets are scattered throughout the core. Very few faults in the Kentucky #3 core are mineralized. The composite rose diagram of slickensides (Figure 3H) has two statistically significant peaks. There is a 1.0% chance that the peak at N05°W does not exist and a 10.0% chance that the peak at N73°E does not exist. A smaller peak which is not statistically significant occurs at N43°W. The equal area projection of slickensides has three clusters: N73°E-65°SW, N05°W-40°SE, and N43°W-0°SE. The N43°W trend is generally found in the Middle Huron Member, and the N05°W and N73°E sets are found in the Lower Huron Member and below.

All three slickenside sets are parallel to mapped or projected normal faults in the area, suggesting that they developed through actual fault movement or by compaction and settling of the rock after fault movement.

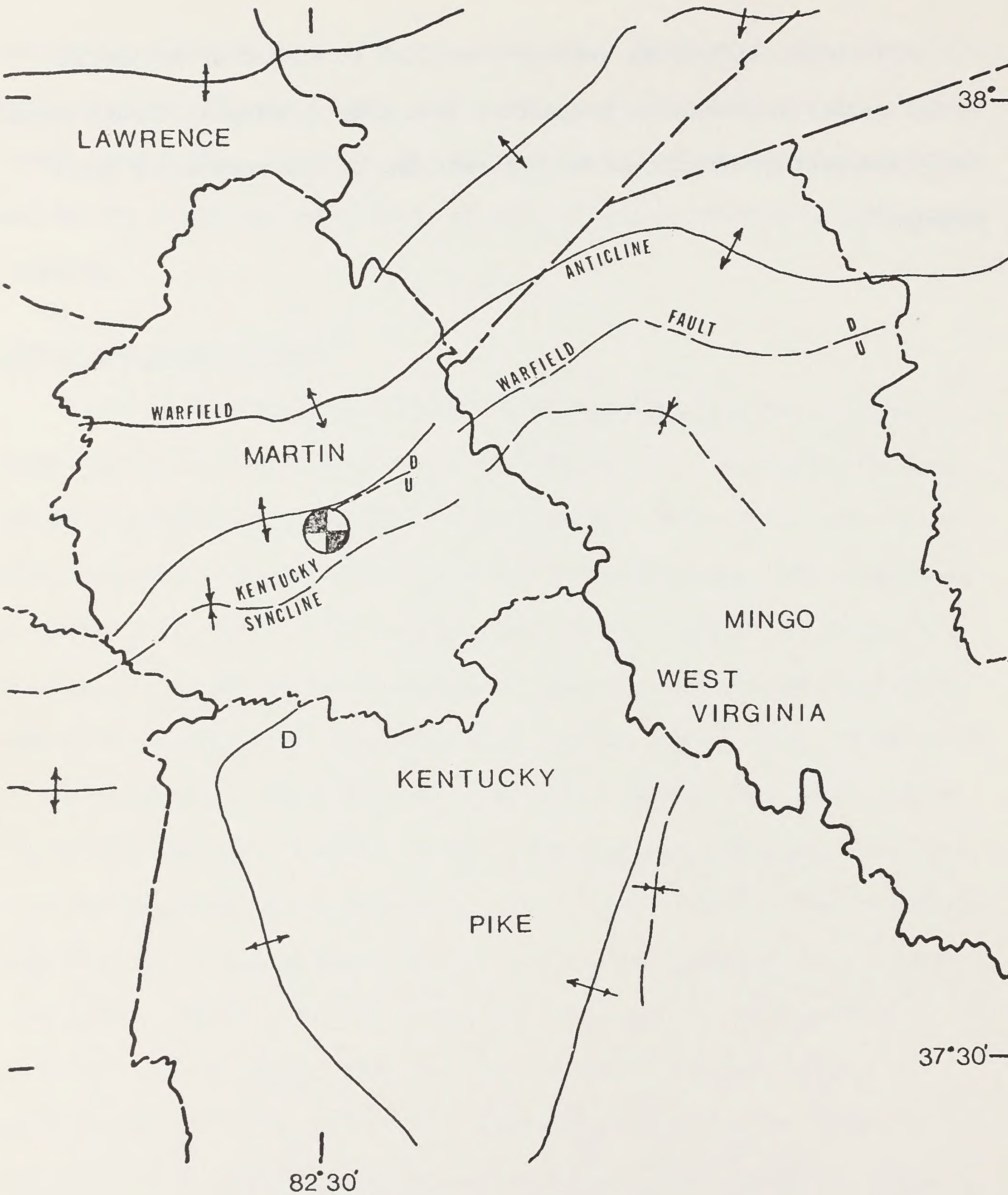
*[1] p. 245

*[2] p. 245

*[3] p. 245

*[4] p. 246

*[5] p. 247.

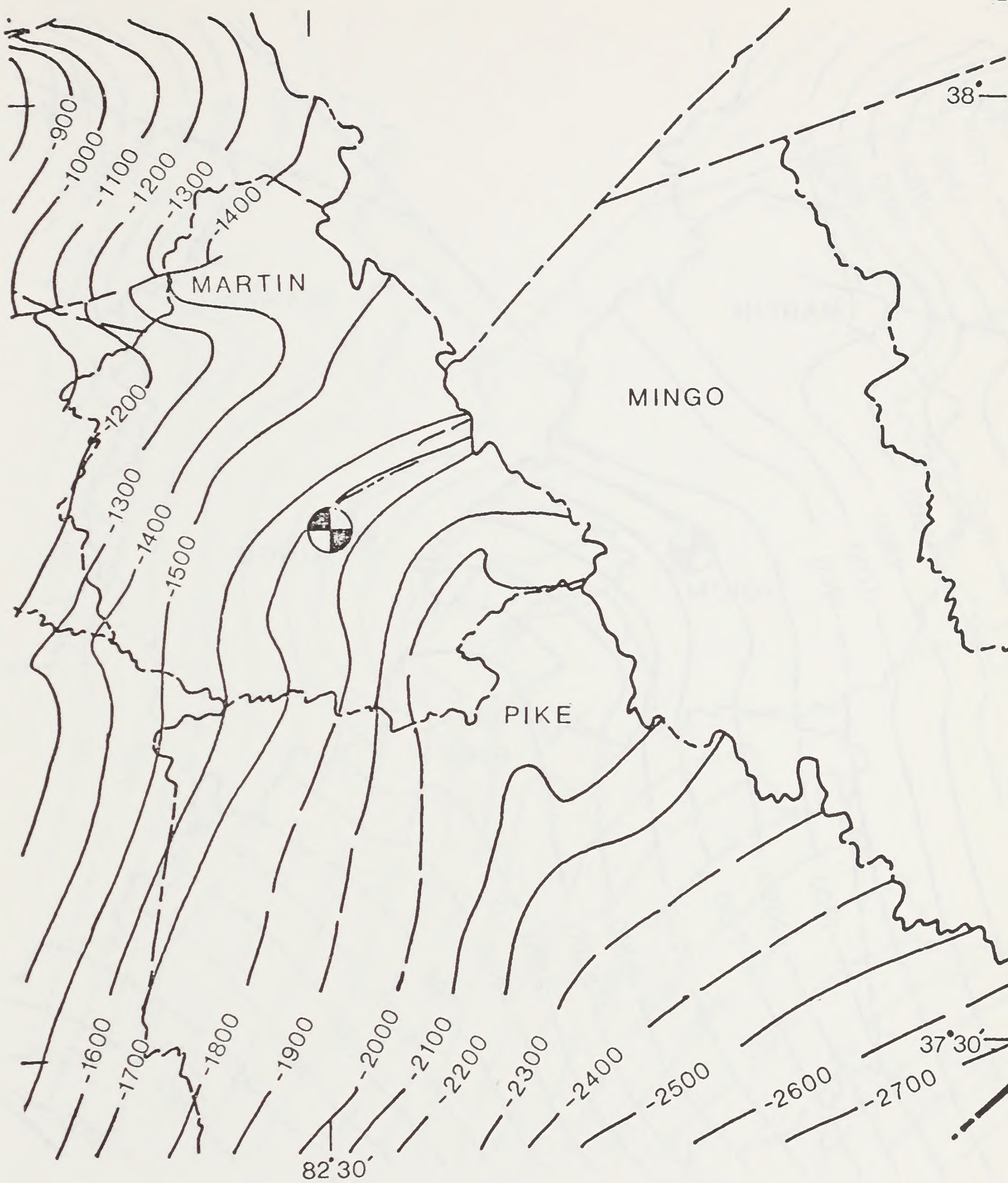


E.G.S.P. KENTUCKY – 3
SURFACE GEOLOGY
SCALE 1:370,000
FIGURE 3A

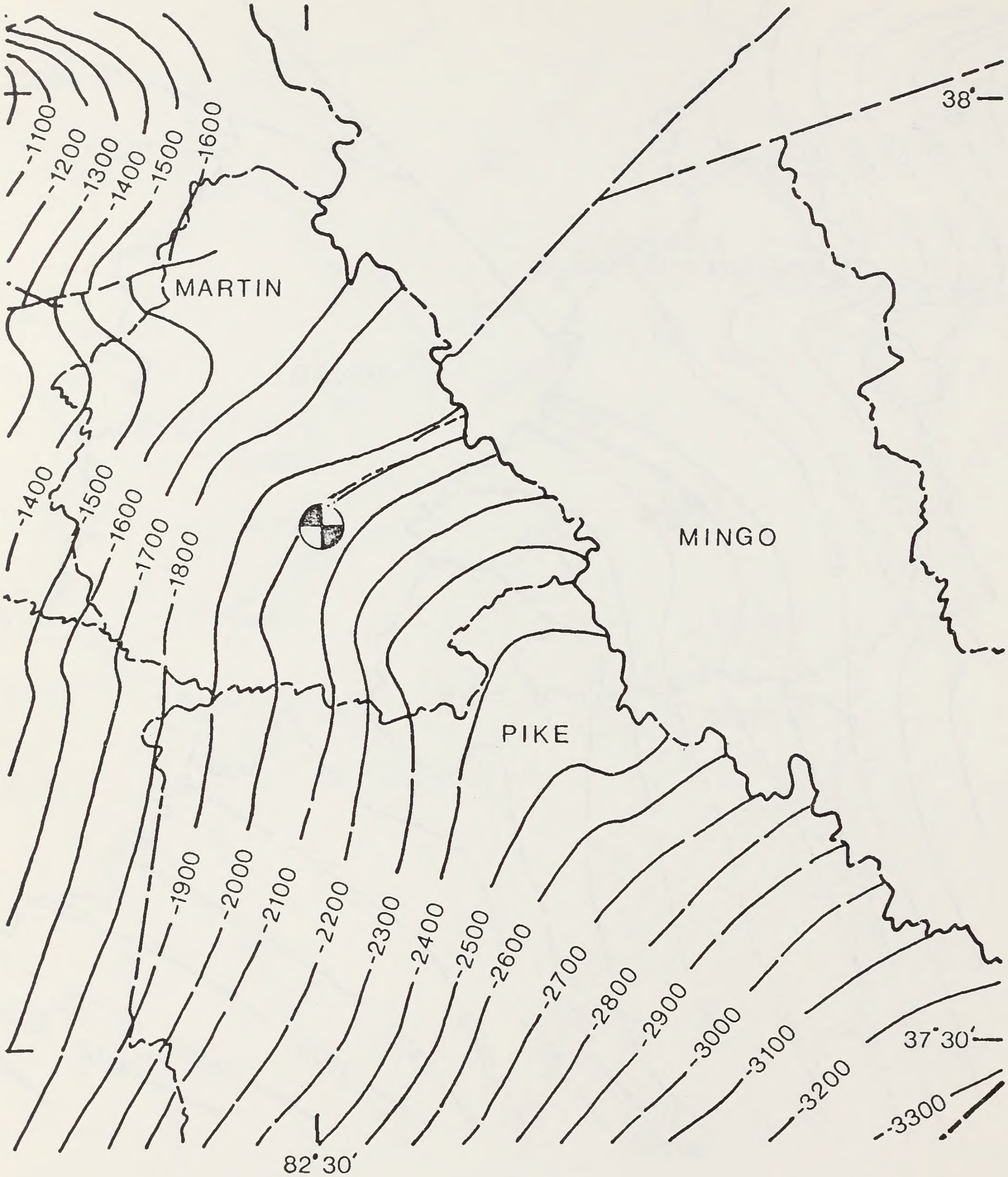
LEGEND: ANTICLINE

SYNCLINE

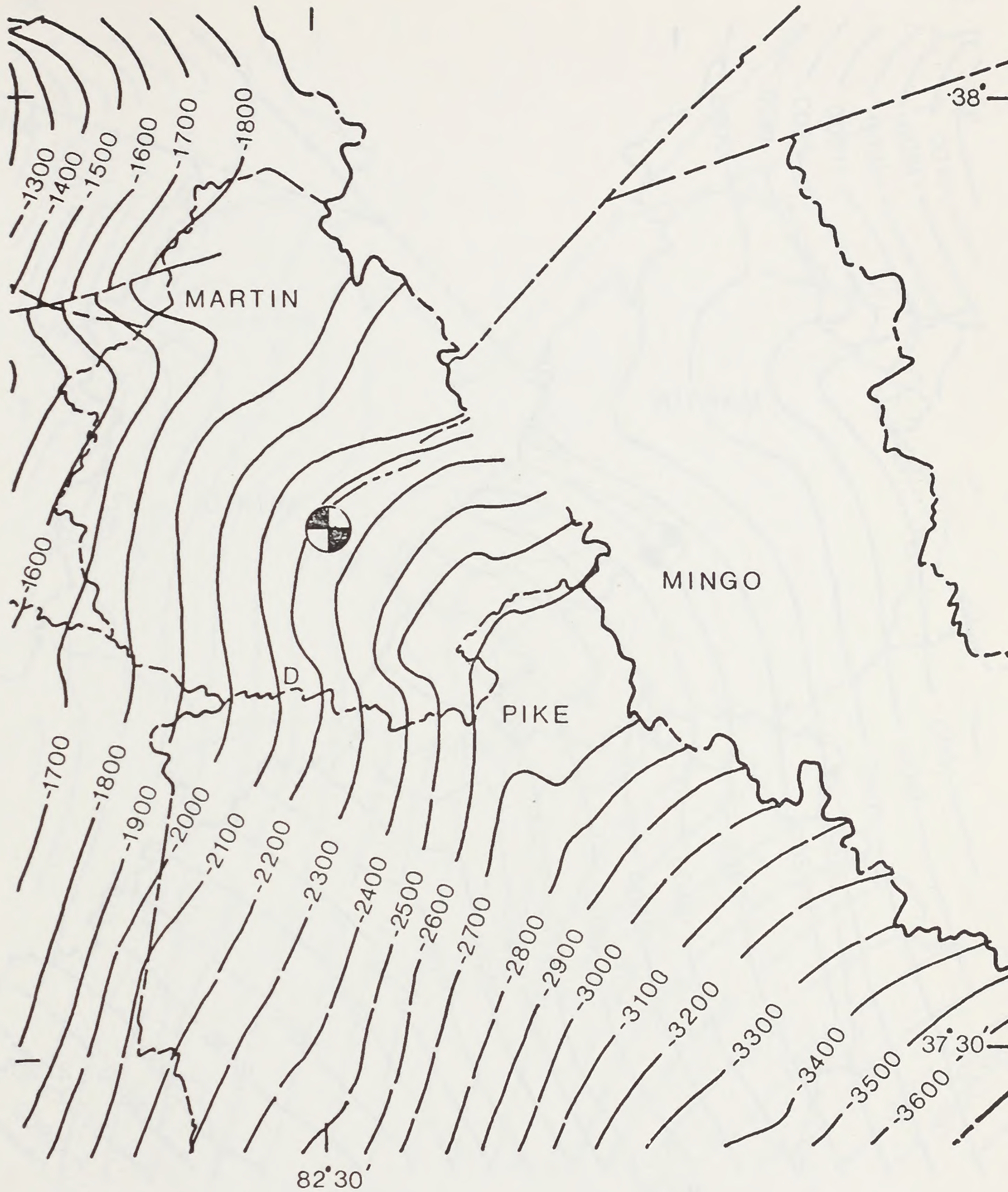
FAULT



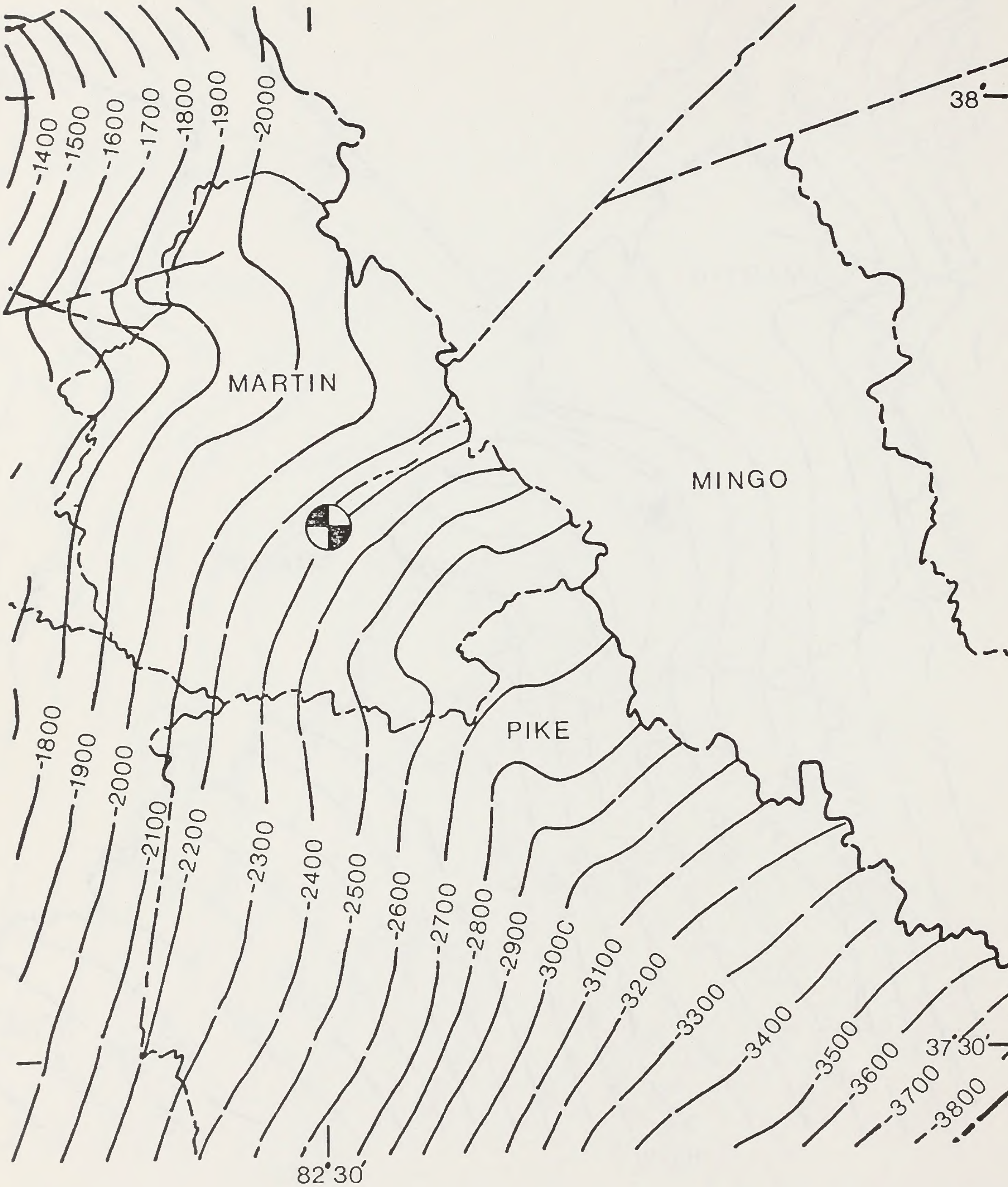
E.G.S.P. KENTUCKY-3
STRUCTURAL CONTOURS
BASE OF THREE LICK BED
SCALE 1:370,000
FIGURE 3B



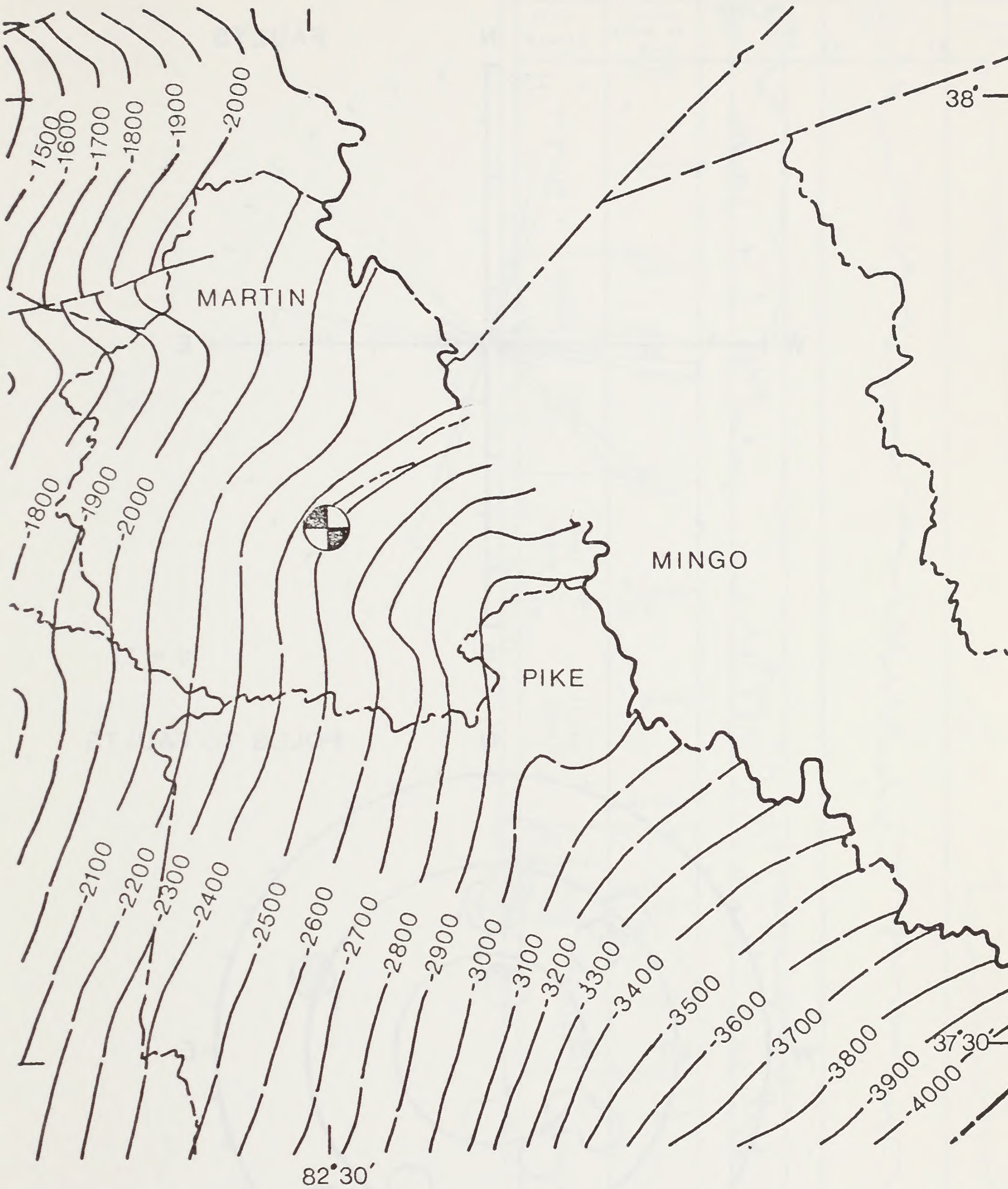
E.G.S.P. KENTUCKY—3
STRUCTURAL CONTOURS
BASE OF MIDDLE HURON
SCALE 1:370,000
FIGURE 3C



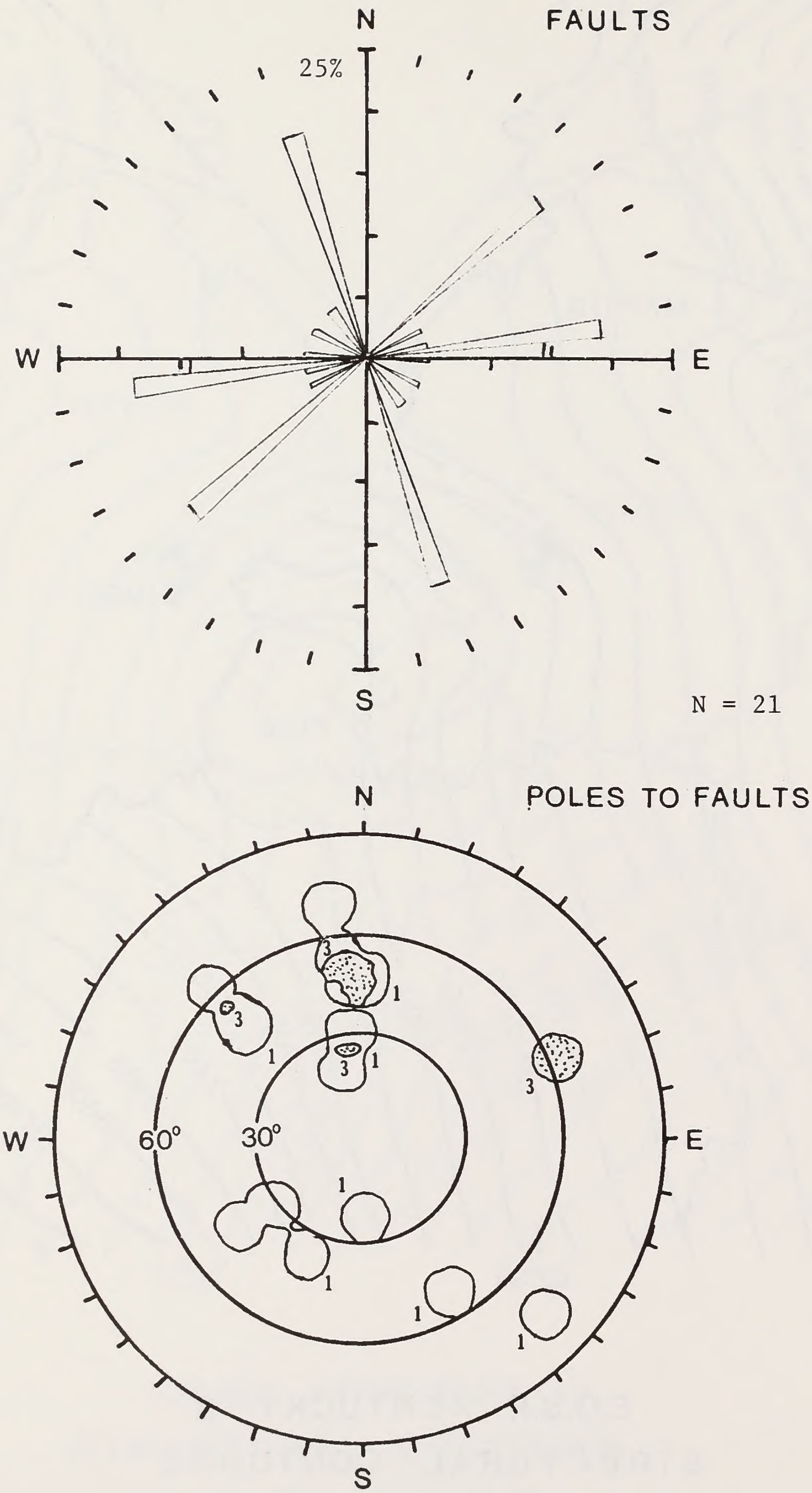
E.G.S.P. KENTUCKY–3
STRUCTURAL CONTOURS
BASE OF LOWER HURON
SCALE 1:370,000
FIGURE 3D



E.G.S.P. KENTUCKY – 3
STRUCTURAL CONTOURS
BASE OF JAVA FM.
SCALE 1:370,000
FIGURE 3E



E.G.S.P. KENTUCKY—3
STRUCTURAL CONTOURS
BASE OF RHINESTREET
SCALE 1:370,000
FIGURE 3F



EGSP-KENTUCKY #3

Figure 3G. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.

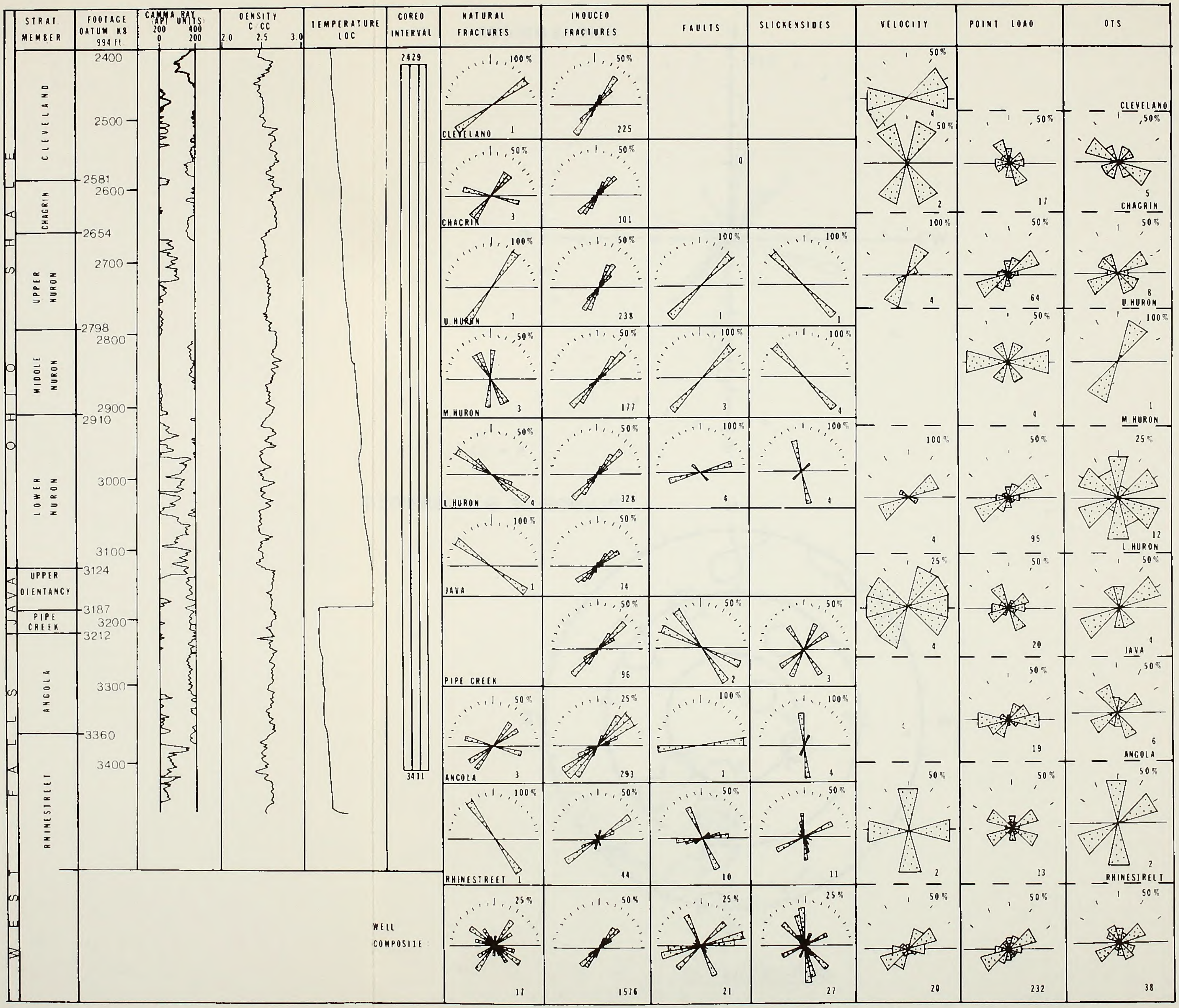


FIGURE 31 EGSP KY # 3 WELL SUMMARY

EGSP-KENTUCKY #4 (SKAGGS KELLY UNIT #3RS) WELL

LOCATION

The EGSP-Kentucky #4 well is located in the Redbush quadrangle of Johnson County, Kentucky, approximately 13 miles northwest of Paintsville (Figures 1, 4A and Table 1). The exact position is 1,780' FNL, 1,320' FEL, Sec. 12, Twp R, Range 79 at a ground elevation of +961' MSL with the Kelly bushing at +972' MSL.

GEOLOGY

The well is situated in the Eastern Kentucky fault system, approximately seven miles north of the Irving-Paint Creek Fault. It is near the middle of the Rome Trough and underlain by Pennsylvanian Age rocks (Renfro, 1970). The surface structure map (Figure 4A) shows the well is positioned on the crest of a NE striking anticline. The subsurface geological structure maps (Figure 4B - 4F) on the Devonian Shale members show a dome underlying the surface anticline which is bounded to the north and south by high angle faults which strike N70°-80°E and have relative movement downward on the south side. The complex structure may be the reason for such diverse trends in the fracture systems and mechanical test data. From 967' to 1,510', 550' of Devonian Age core was taken. The formations penetrated and the intervals cored are recorded in the Well Summary Chart (Figure 4I).

PRODUCTION DATA

A gas show, illustrated by a deviation in the temperature log (Figure 4I), occurs in a zone of inclined unmineralized fractures at 1,307'-1,310' (Evans, 1980). Two zones and portions of three members

were stimulated: the Huron Shale from 1,294' to 1,382' and the Cleveland and Chagrin Shales from 1,010' to 1,120'. Open flow increased from 0 to 28 mcf in the lower zone, and from 0 to 16 mcf in the upper zone. The hydrofracture in the upper zone extended to an H_2S zone. The well is shut in and has not produced commercial gas (Horton, 1981).

CORING-INDUCED FRACTURES

The majority of coring-induced fractures are either disc or torsional types. Three petal fractures include two in unoriented core, one oriented N50°W.

NATURAL FRACTURES

Ten joints occur in three members of the Ohio Shale in the Kentucky #4 core. The joints form three trends as follows:

Trend 1: N52°E to N77°E, near vertical with a concentration of fracture strikes trending N67°E.

Trend 2: N31°E to N44°E, near vertical.

Trend 3: N54°E to N61°E, dipping 46°NW.

Trend 1 consists of four fractures in the Cleveland Shale. These fractures are in strongly folded (soft-sediment deformation ?) shales and are mineralized with calcite, or with dolomite and disseminated pyrite.

Trend 2 consists of a single small fracture in the Middle Huron Shale. It is mineralized with calcite and is surrounded by strongly distorted bedding.

Trend 3 consists of five medium angle ($\sim$45° dip) nonmineralized fractures in the top of the Lower Huron. These fractures exhibit very coarse planar surfaces and may be identified by large deflections on both sibilation and temperature geophysical logs (Phase II).

Figures 4B to 4F show structural contours (Dillman, et al., 1980) on the bases of the members penetrated by Kentucky #4, where available. Joint bearing formations have joint orientations superimposed on the well location. The dome structure and bounding faults indicate a complex geological system acting on these members. Joint trends indicate wrench-fault movement in this block.

The faults and microfaults occur almost exclusively in the Berea Sandstone, Bedford Shale and Olentangy Shale. The majority are microfaults whose surfaces are curviplanar; therefore strikes and dips are approximated or are not determined. A Schmidt net of poles to fault planes appears in Figure 4G. The formations shown are the Berea Sandstone, the Bedford Shale and the Olentangy Shale. No strong trend is shown. The microfaults in the Bedford Shale and Berea Sandstone occur at contacts between sandstone and mudstone which are strongly folded and distorted due to slumping and soft-sediment deformation, thus explaining the lack of a strong trend in these members. Schmidt net diagrams of poles to slickenside bearing and plunge are shown for the Bedford Shale, the Berea Sandstone and the Olentangy Shale (Figure 4H). A trend is evident in the slickensides in the Olentangy Shale, shown in the southwest quadrant, as three of the four bear N32°E to N44°E.

MECHANICAL TEST DATA

The pretest fractures show a major northeast trend in the well composite. This trend is consistent for most of the individual members with three exceptions: a major northwest trend in the Upper Huron; two approximately equal major trends in the Olentangy (N30°E and N30°W); a primary trend in the Chagrin at N30°E and a secondary trend at N60°W. Rose diagrams of these and other trends can be seen in Figure 4I.

A composite of ultrasonic velocity test results indicates the major preferred orientation is northeast, whereas a lone Chagrin Shale sample is oriented N30°W. The Upper Huron Shale exhibits nearly equal trends of N30°W and N60°E. The Middle and Lower Huron Shales have nearly identical preferred orientations of N30°E, N60°W, and E-W. The Olentangy Shale has a preferred orientation of N60°E.

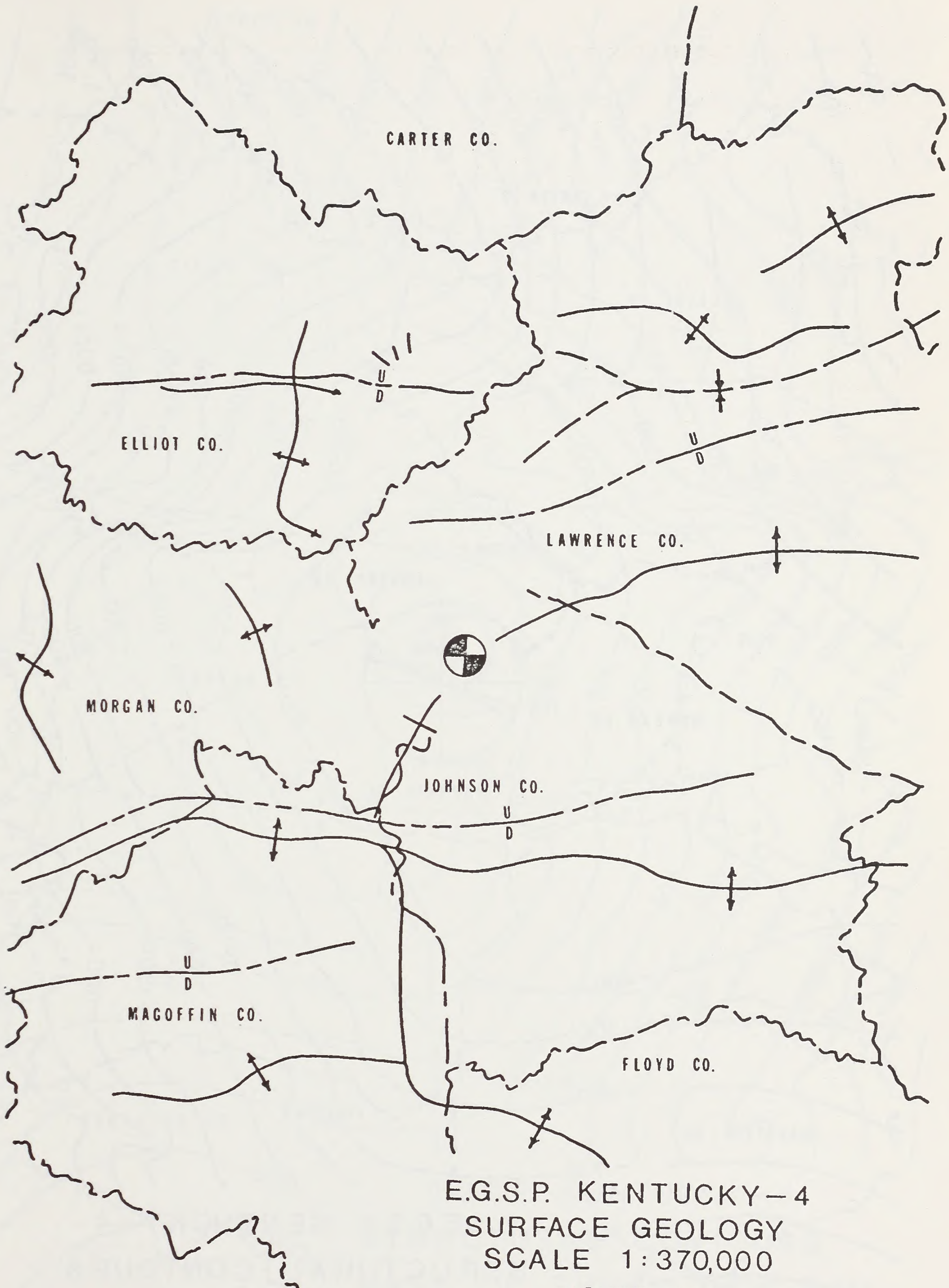
The well composite diagram of the point load tests also shows the highest percentage of test results at N60°E with relatively high percentages at N30°E and E-W. In the individual members, the Bedford Shale has a N60°E preferred orientation while the Cleveland Shale has equal preference for N60°E and E-W. The Chagrin Shale shows no strong preference with equal numbers of test results in the N30°E, E-W and N30°W directions. The Upper Huron departs from the majority of formations with the principal preferred orientation to the north and a secondary orientation at N60°E. The Middle and Lower Huron Shales have similar orientation preferences as they have for the ultrasonic velocity tests. The primary orientation is N60°E with strong secondary orientations at N30°E and E-W. The Olentangy also departs from the majority of mechanical test results

with the primary preferred orientation of N60°W and a strong secondary preferred orientation of N30°E.

The directional tensile strength (DTS) tests indicate N60°E as the strongest preferred orientation with N30°E and N30°W also strongly preferred. The other mechanical tests and the joints also show a preference for N60°E. A northeast orientation is one of the three strong trends in the Kentucky #4 faults. The single test in the Berea Sandstone indicates a northeast orientation, agreeing with results from the velocity and point load and, in part, with the pretest fractures. Fault trends in the Berea do not agree with the mechanical test data. The Cleveland Shale DTS tests show nearly equal preference for N-S and N60°E orientations, similar to the results of the point load tests. The pretest fractures and velocity tests both have N60°E preferred orientations, close to the N70°E preference exhibited by the joints. However, the one orientable petal fracture in the well occurs in the Cleveland Shale and has a N50°W strike. The DTS test results show an equal preference for N-S and N30°E orientations in the Upper Huron. Results from mechanical tests and from natural fractures in both the Chagrin and the Upper Huron Shales show no definite preferred orientation. The results in both the Middle and Lower Huron Shales DTS tests indicate a northeastern preferred orientation which is compatible with the other mechanical test results and the natural fracture data for the member. The velocity data in both members also have secondary E-W and N60°W preferred orientations. The DTS test results in the Olentangy Shale show equal preference for the N60°E, E-W and N30°W directions. The other mechanical test results and natural fracture information in the Olentangy do not

indicate a single strong preferred orientation with the exception of a N60°E trend in the velocity tests.

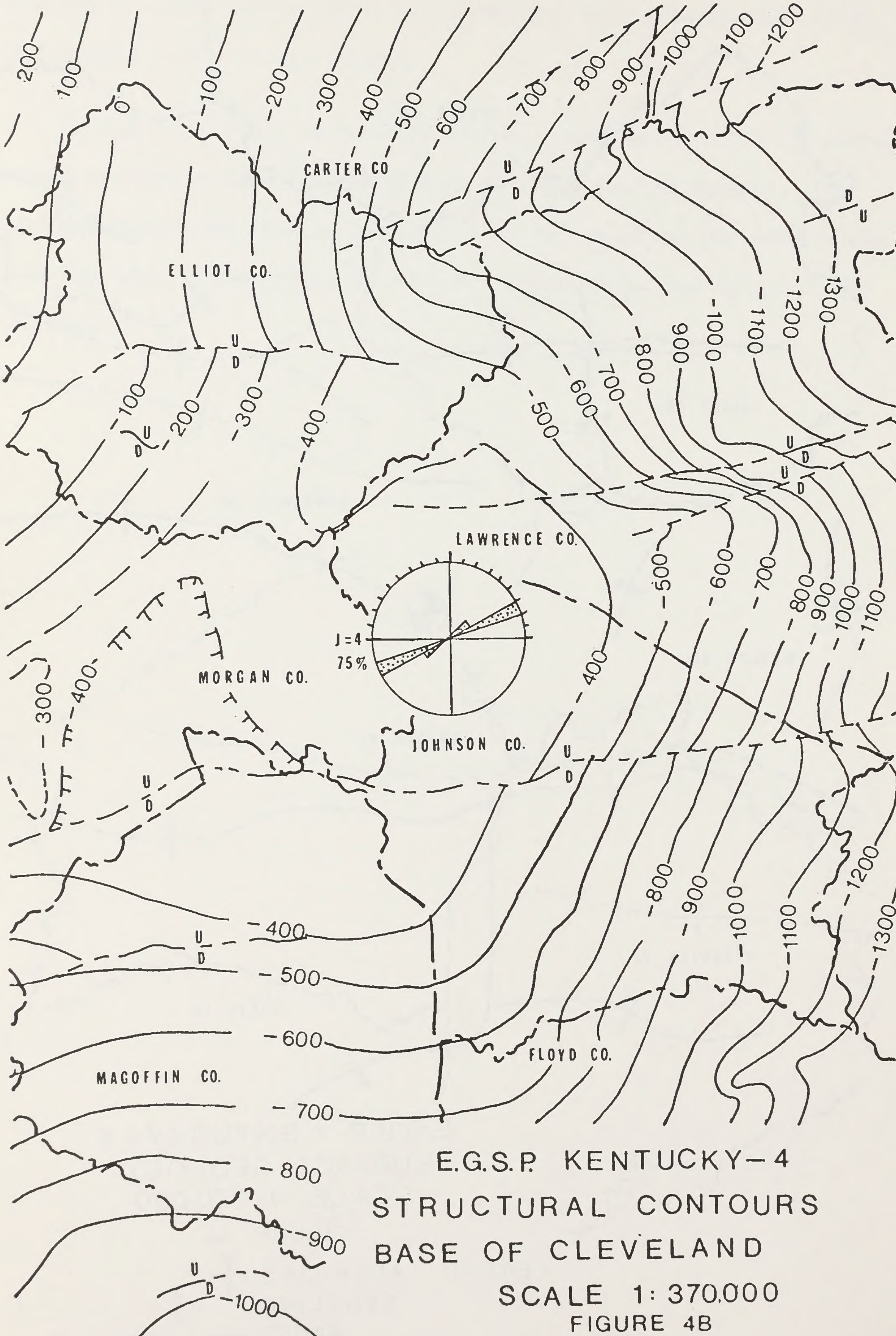
Overall, the N60°E orientation probably indicates a fabric developed during the early stages of deformation of the Allegheny Orogeny. The variability in test results is most likely due to latter deformation and faulting that is known to occur through Mississippian Age sediments in this area.



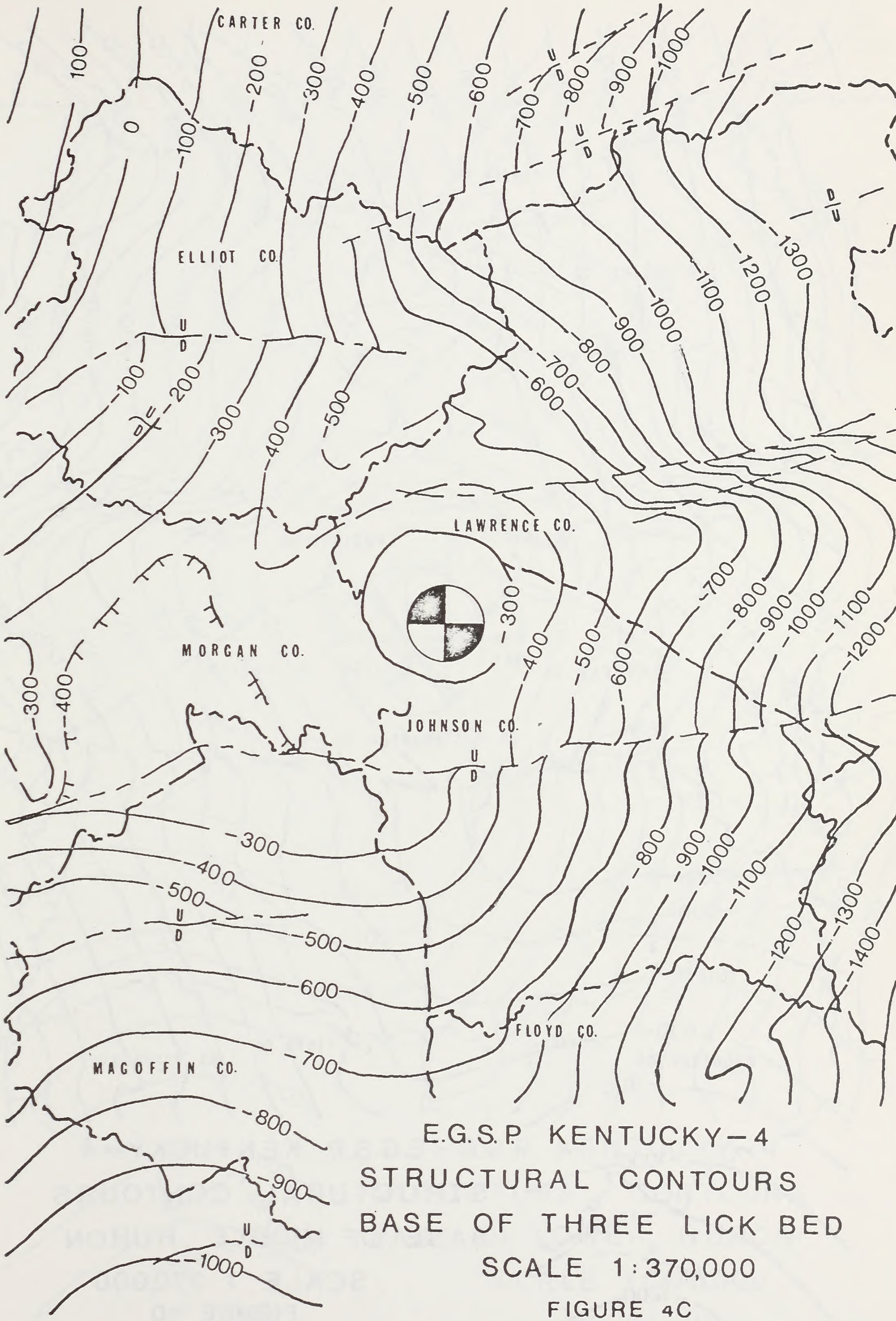
E.G.S.P. KENTUCKY – 4
SURFACE GEOLOGY
SCALE 1:370,000

FIGURE 4A

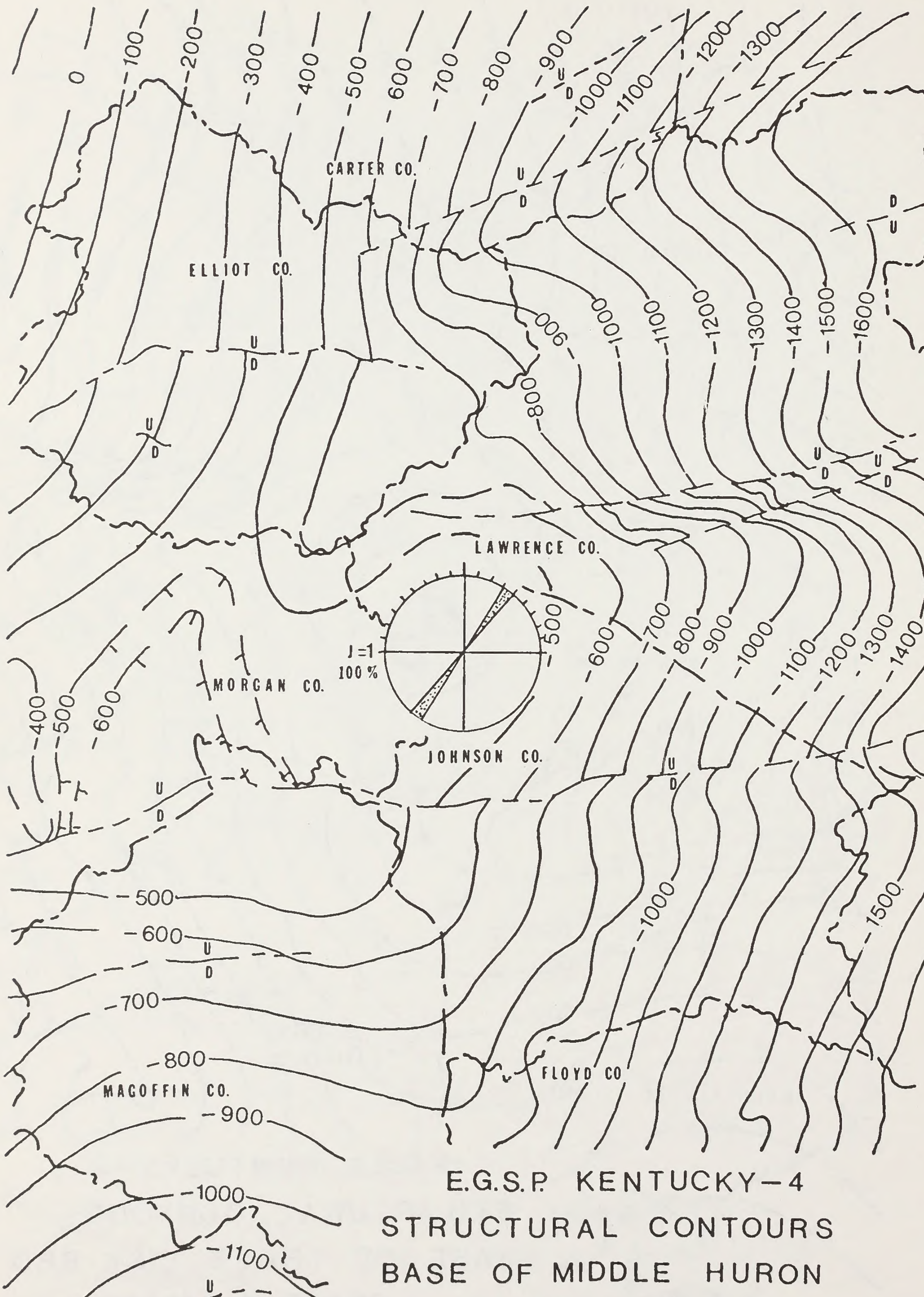
LEGEND: ANTICLINE
SYNCLINE
FAULT



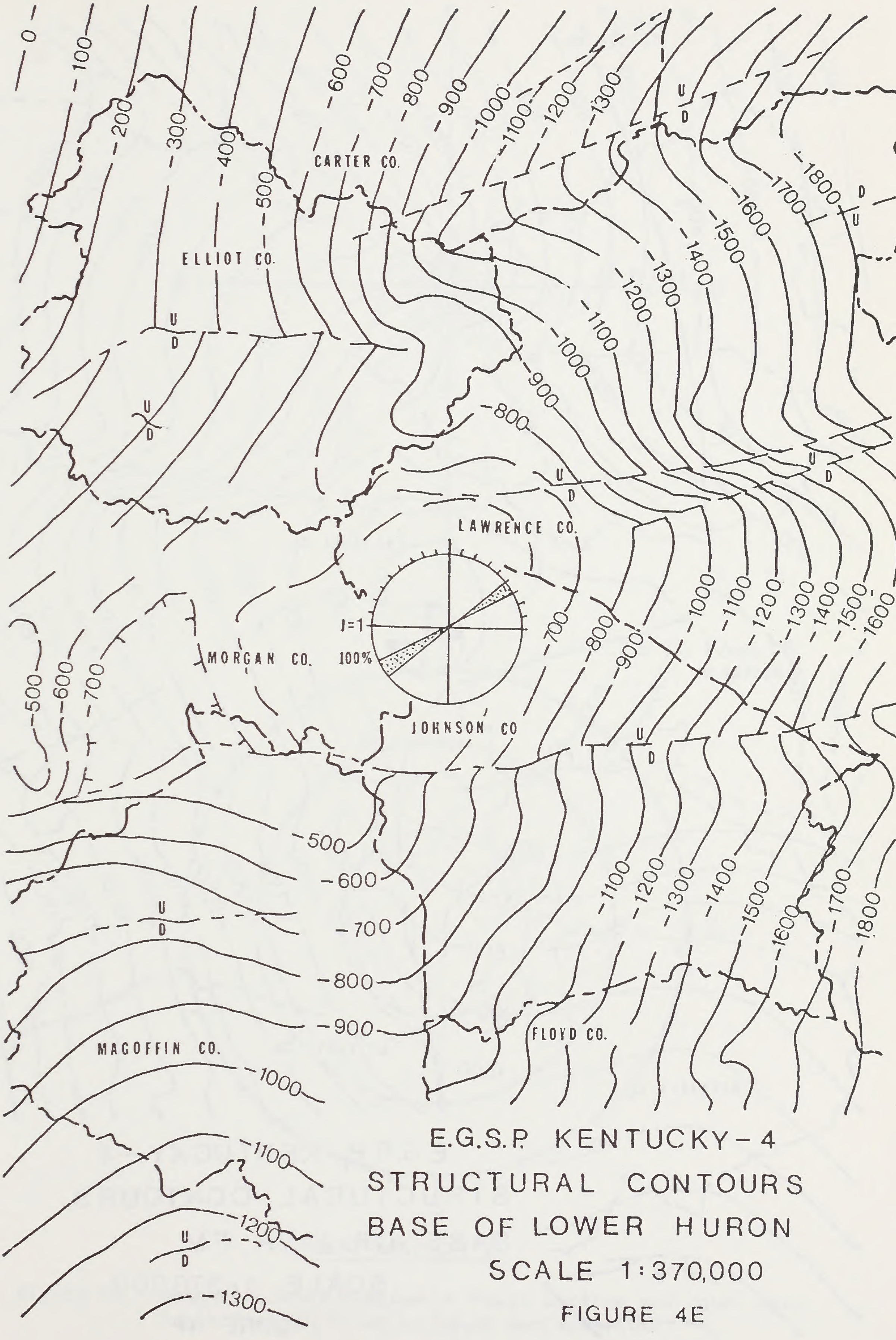
E.G.S.P. KENTUCKY-4
STRUCTURAL CONTOURS
BASE OF CLEVELAND
SCALE 1: 370,000
FIGURE 4B



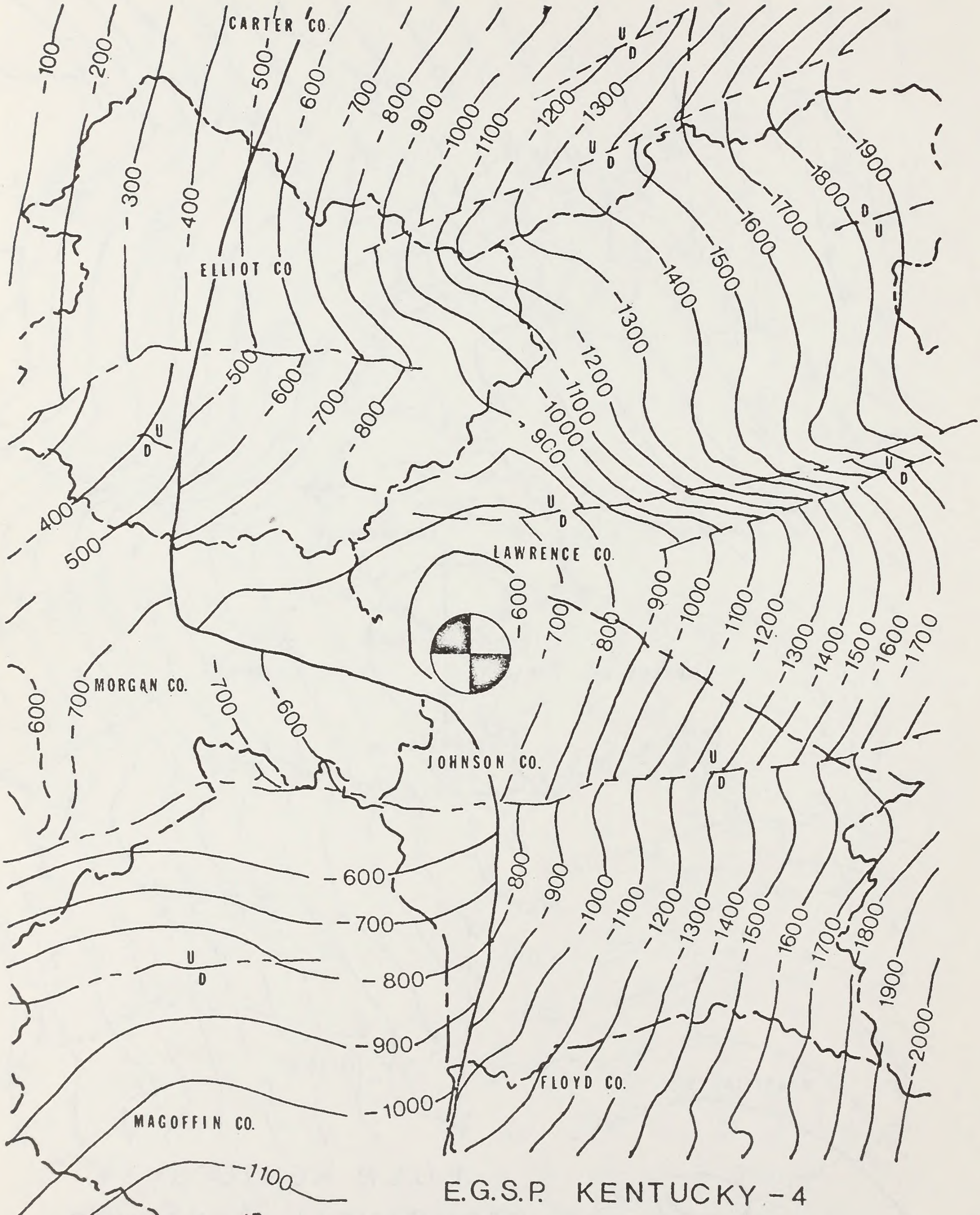
E.G.S.P. KENTUCKY-4
STRUCTURAL CONTOURS
BASE OF THREE LICK BED
SCALE 1:370,000
FIGURE 4C



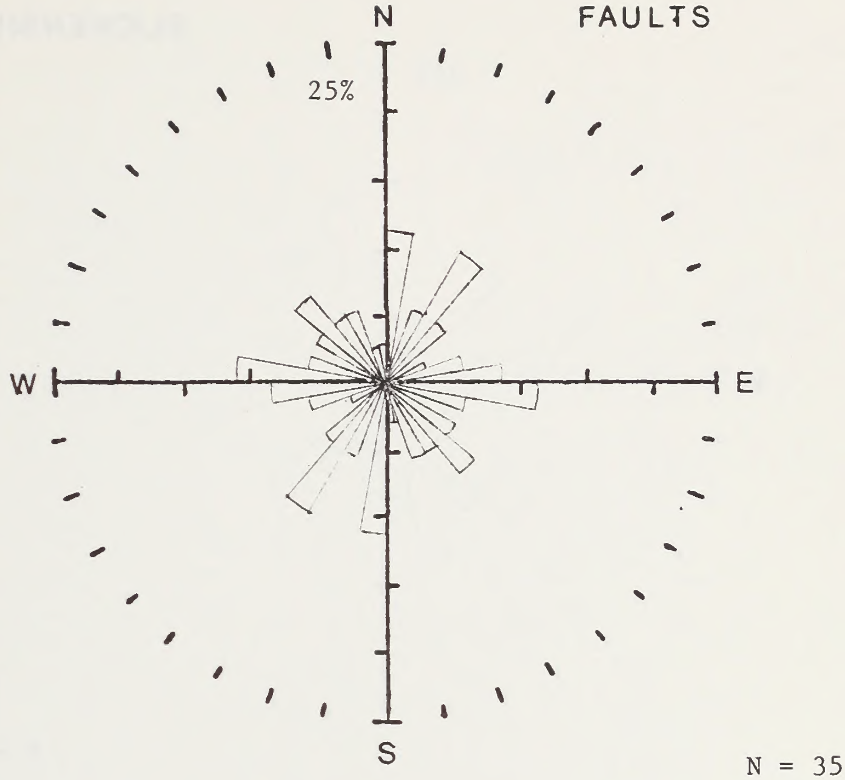
E.G.S.P. KENTUCKY–4
STRUCTURAL CONTOURS
BASE OF MIDDLE HURON
SCALE 1:370,000
FIGURE 4D

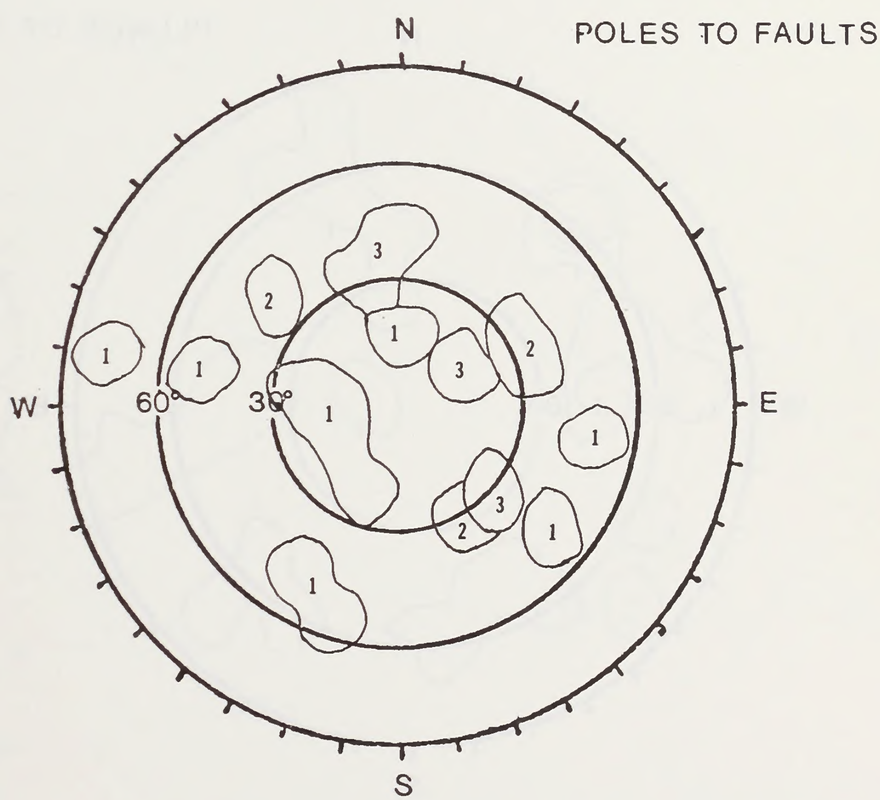


E.G.S.P. KENTUCKY-4
STRUCTURAL CONTOURS
BASE OF LOWER HURON
SCALE 1:370,000
FIGURE 4E



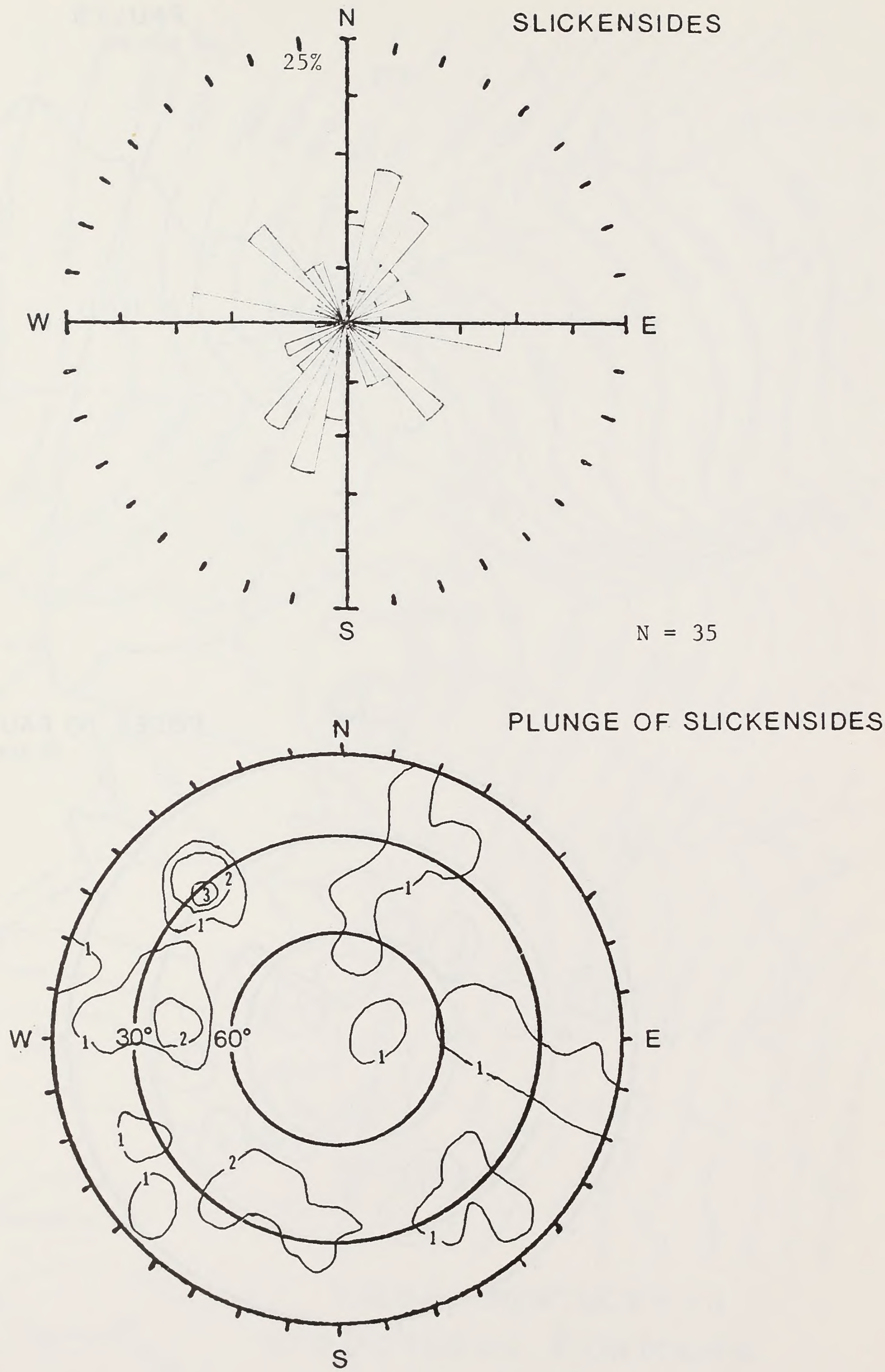
E.G.S.P. KENTUCKY-4
STRUCTURAL CONTOURS
BASE OF JAVA FM.
SCALE 1:370,000
FIGURE 4F





EGSP-KENTUCKY #4

Figure 4G. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.



EGSP-KENTUCKY #4

Figure 4H. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.

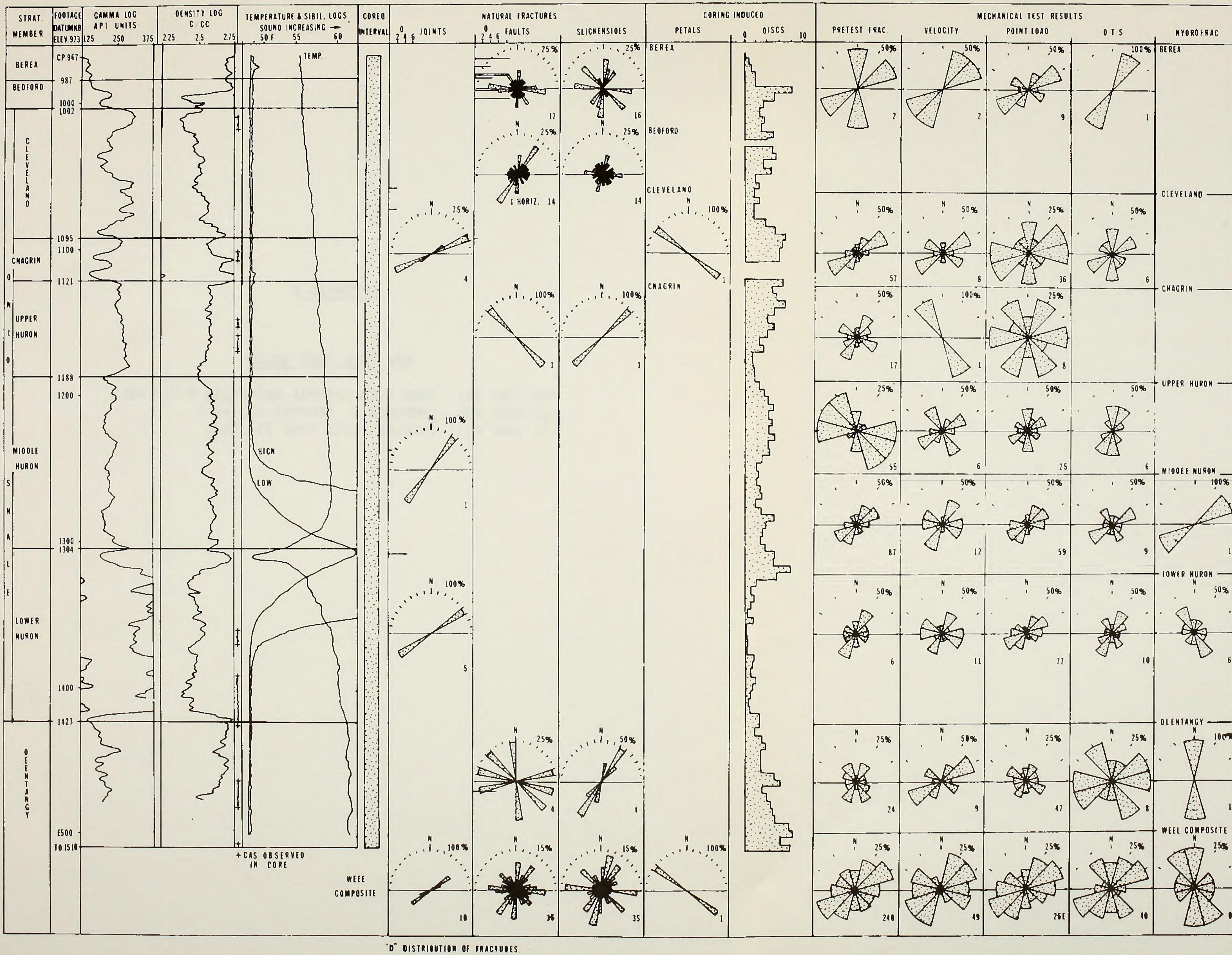


FIGURE 41 E.G.S.P. KENTUCKY 4 WELL SUMMARY.

CLIFFS MINERALS INC.

APPENDIX B

NEW YORK EGSP WELLS

NEW YORK #1: (NEW YORK NATURAL GAS #6213 (JO)) WELL
NEW YORK #3: (AMBROSE E. SCUDDER #1) WELL
NEW YORK #4: (VALLEY VISTA VIEW #1) WELL

EGSP-NEW YORK #1 (NEW YORK NATURAL GAS #6213 (JO)) WELL

LOCATION

The EGSP-New York #1 well is located at 9,430'S of latitude 42°22'30" and 7,620'W of longitude 77°47'30" in Allegany County, New York at a ground level elevation of 1,839.7'. Geophysical log datum is 1,852.7' (Figures 1, 1A and Table 1).

GEOLOGY

The well site is situated in the Canadaway Group of the Upper Devonian Shales in an area of broad folding with fold axes trending northeast-southwest. Associated with the folding are faults that parallel the fold axes and may be the result of deformation and detachment in the underlying Silurian evaporites. Coring started in the Dunkirk Member of the Java Formation at 370' and ended in the Tully Limestone at 2,929'. A total of 2,409' of core was taken from five separate intervals (Figure 1H).

PRODUCTION DATA

No production has been reported from New York #1. Temperature and sibilation logs indicate only small shows with little correlation to the fractures present. A possible gas bearing zone from 2,325' to 2,395', which may be associated with a set of E-W vertical fractures, occurs at the bottom of the West Falls Formation and extends into the uncored Sonyea Formation. A slight deviation in the temperature log along with anomalous sonic log data also suggests gas occurrence in the interval.

CORING-INDUCED FRACTURES

Examination of photologs of the core and the Cliffs Minerals, Inc. Phase II Report shows no coring induced fractures other than disc fractures.

NATURAL FRACTURES

The cored intervals within the Perrysburg Formation, Java Formation, and Angola Member of the West Falls Formation display a definite E-W fracture trend. At 1,490', near the top of the Rhinestreet Member of the West Falls Formation, a NW joint trend begins and occurs sporadically down core to the base of the Sonyea Formation. The Rhinestreet contains a fracture trend that rotates from N70°W through E-W to N70°E, from the top to the bottom of the interval (2,080' to 2,335'). The rotation may be associated with the structural change defined in Figures 1C and 1D. In the Sonyea Formation the fracture system is rotated slightly more to N50°E with a single fracture at N35°W corresponding to the fracture set at the top of the Rhinestreet Member. The Genesee Formation displays a N60°E trend near the top, rotating to a N80°W trend near the underlying Tully Limestone. Figures 1B through 1F compare natural fracture trends to structural contours at the base of the formation containing the fractures. Figure 1G shows the structural contours on the base of the Lower Hamilton Group. The rotation of the joint strike suggests a changing stress that may be the result of wrench-type movement between the NE trending faults shown on the diagrams.

Slightly over 50 percent of the fractures are mineralized with calcite, dolomite or pyrite. No definite relationship between joint trends and joint mineralization was noted, but the joints usually were filled

with either calcite or dolomite. Only one 4.2' joint extending from 2,220.8' to 2,225.0' contains both minerals.

Only three microfaults and a thin microfault zone are noted in the entire core. The first occurs at 1,752.9' in bitumen as a curviplanar surface with slickensides bearing N30°E. The second occurs at 1,848.8' as a curviplanar surface with slickensides bearing N15°W. These structures are the only natural fractures to occur in the interval from 1,490.9' to 2,927.7' in the Rhinestreet Member. The third is a zone containing five microfaults that occurs in the Genesee Formation from 2,730.6' to 2,732.3' and is associated with a soft sediment deformation structure. These microfaults have slickensides which trend N20°W. The fourth microfault occurs at 2,749' as a curviplanar surface with calcite and pyrite and a slickenside trend of N35°E. The movement on the minor faults is normal to fold axes in the area and indicates some movement related to the Allegheny Orogeny.

MECHANICAL TEST DATA

Pretest fracture orientations, point load tests, and directional tensile strength measurements taken on samples from the Perrysburg Formation show a definite weakness in the N60°E direction. Results of directional velocity tests suggest a weakness trend of E-W $\pm$ 15° which compares very well to natural fracture orientations within this formation (Figure 1H).

The Java Formation shows a preferred direction of fracturing at N60°E $\pm$ 15° as suggested by the pretest fracture orientations, velocity tests and point load tests. The directional tensile strength tests show

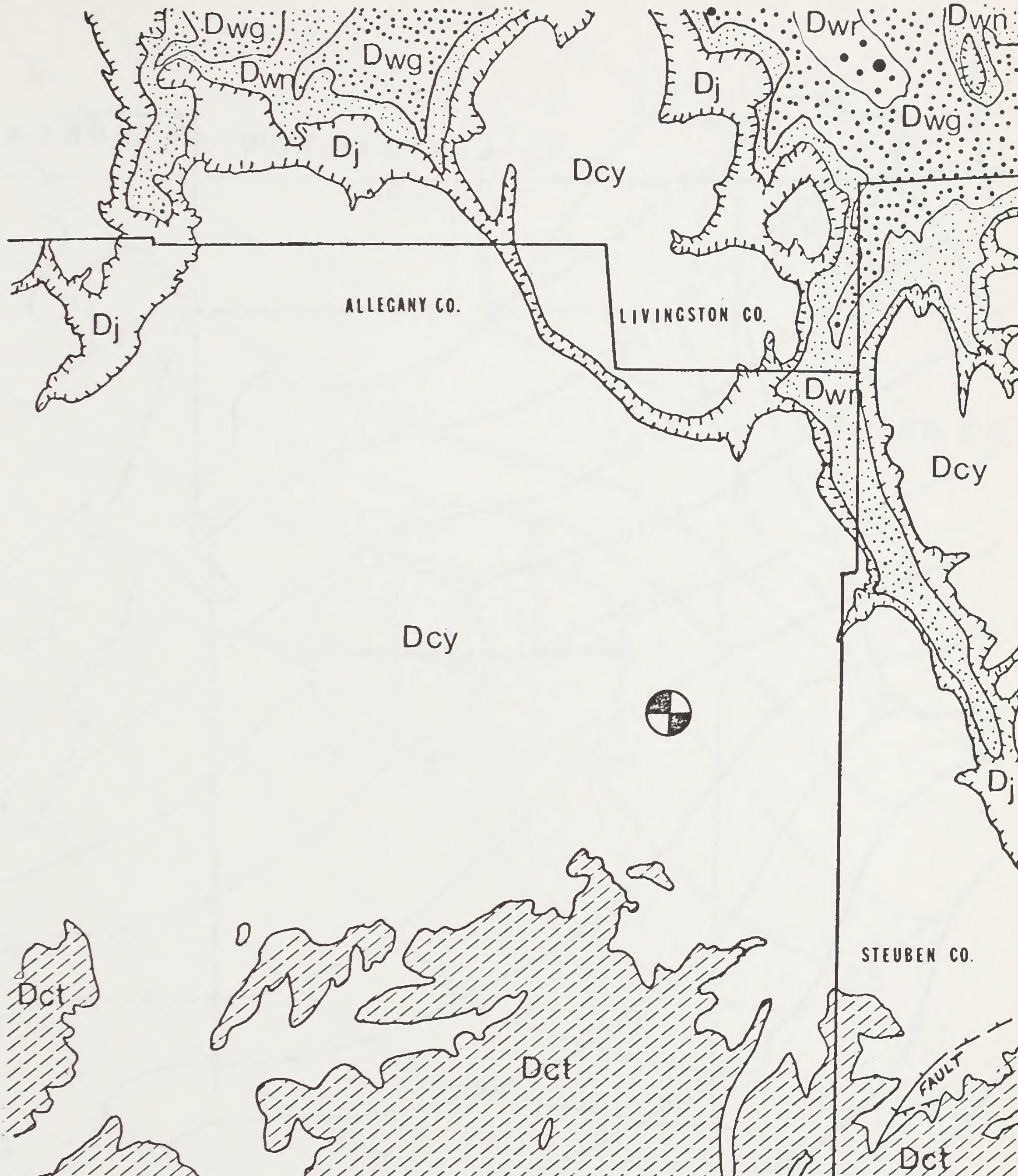
a random orientation. A natural fracture trend of N90°E does not correlate with any of the above orientations (Figure 1H).

A N60°E $\pm$ 15° trend is also pronounced in the West Falls Formation in the pretest fracture, velocity and point load tests. Directional tensile strength trends are very random for this section. The natural fracture trend at N70°E corresponds roughly to the above trends (Figure 1H).

In the Sonyea Formation, point load and velocity agree somewhat with pretest fractures at N60°E $\pm$ 15°, and directional tensile strength test results show random orientation. The natural fracture trend is N50°E for this member (Figure 1H).

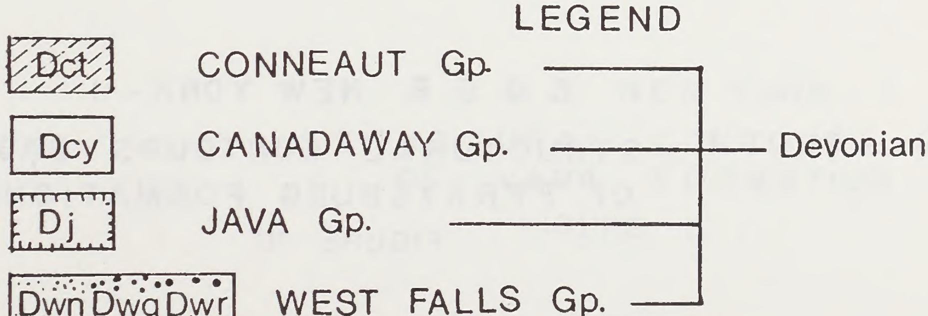
The Genesee Formation shows a completely different trend of pretest fractures at N30°W $\pm$ 15° with point load and velocity still occurring at N60°E $\pm$ 15°. Directional tensile strength tests show a random orientation. The natural fracture trend is N70°E and N80°W (Figure 1H).

The well composite shows a definite N60°E $\pm$ 15° trend on the pretest fracture, velocity, and point load tests, with a secondary orientation at E-W. Directional tensile strength tests show random orientation. The fabric defined by the tests is likely a result of the initial stresses developed during the Allegheny Orogeny as the stresses parallel the fold axes in the area.



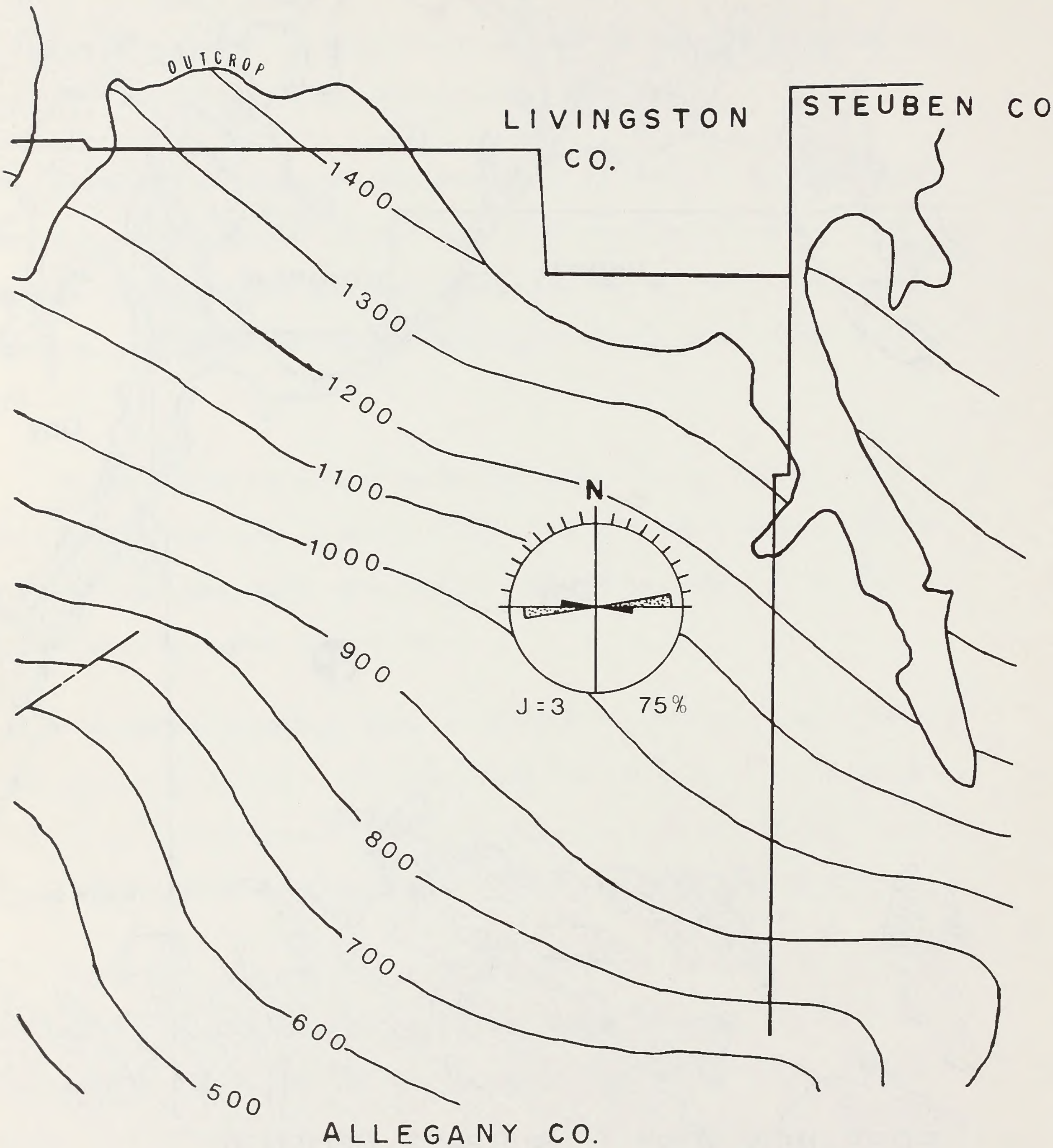
E.G.S.P. NEW YORK-1 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND



SCALE 1 : 250,000

FIGURE 1A

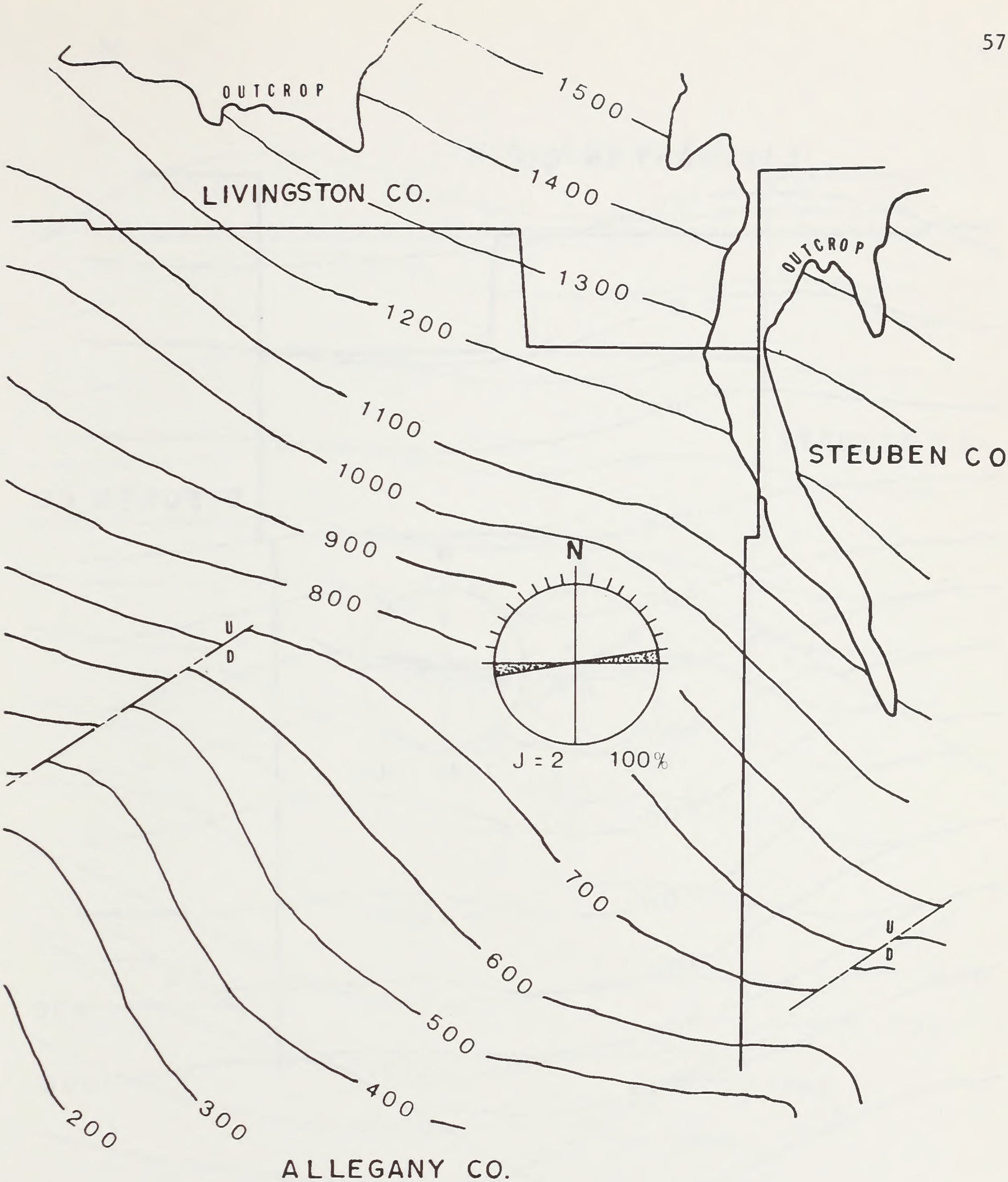


E. G. S. P. NEW YORK - I

STRUCTURAL CONTOURS BASE OF PERRYSBURG FORMATION

FIGURE 1B

SCALE 1 : 250,000

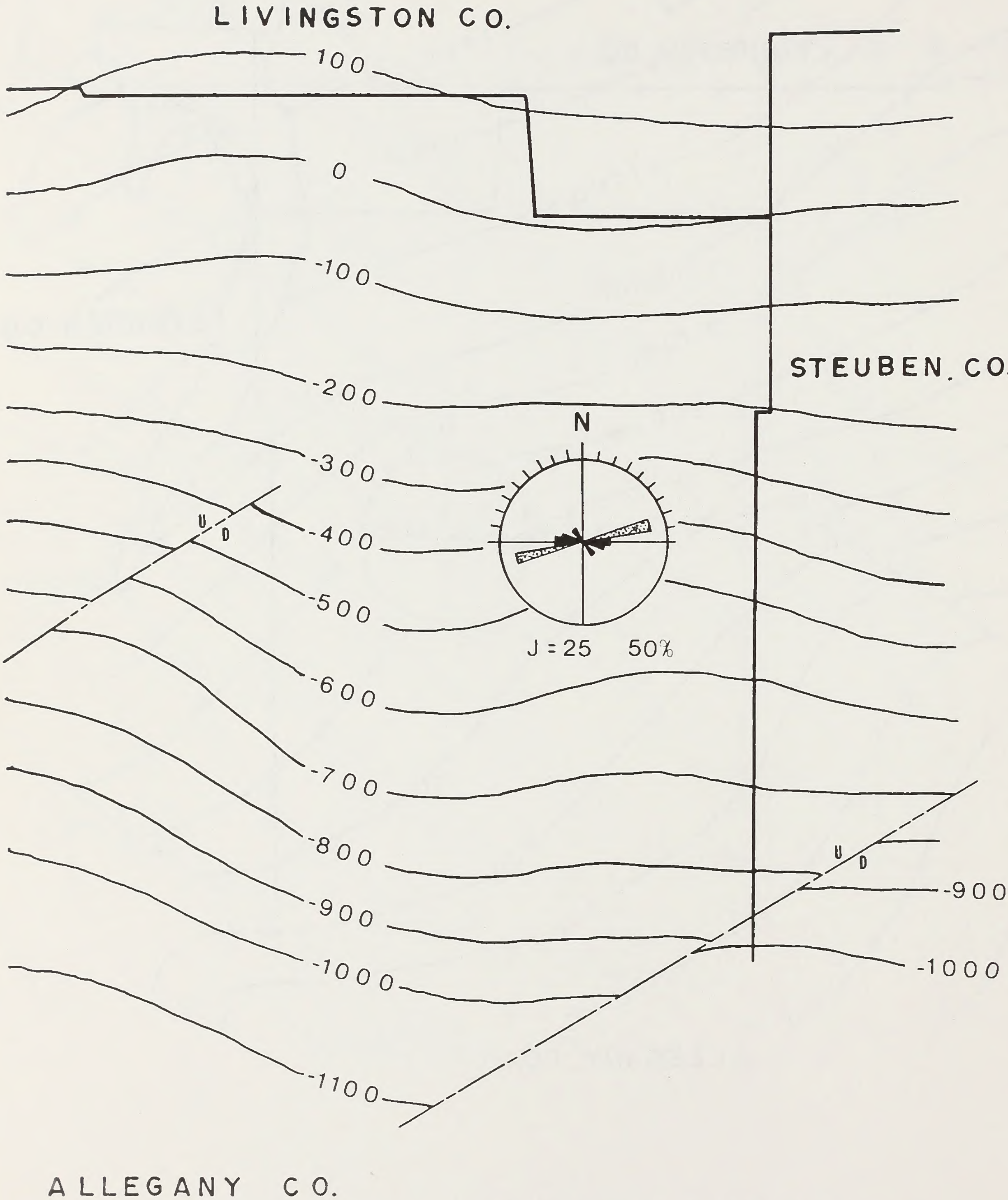


E. G. S. P. NEW YORK - I

STRUCTURAL CONTOURS BASE OF JAVA FORMATION

FIGURE 1C

SCALE 1:250,000

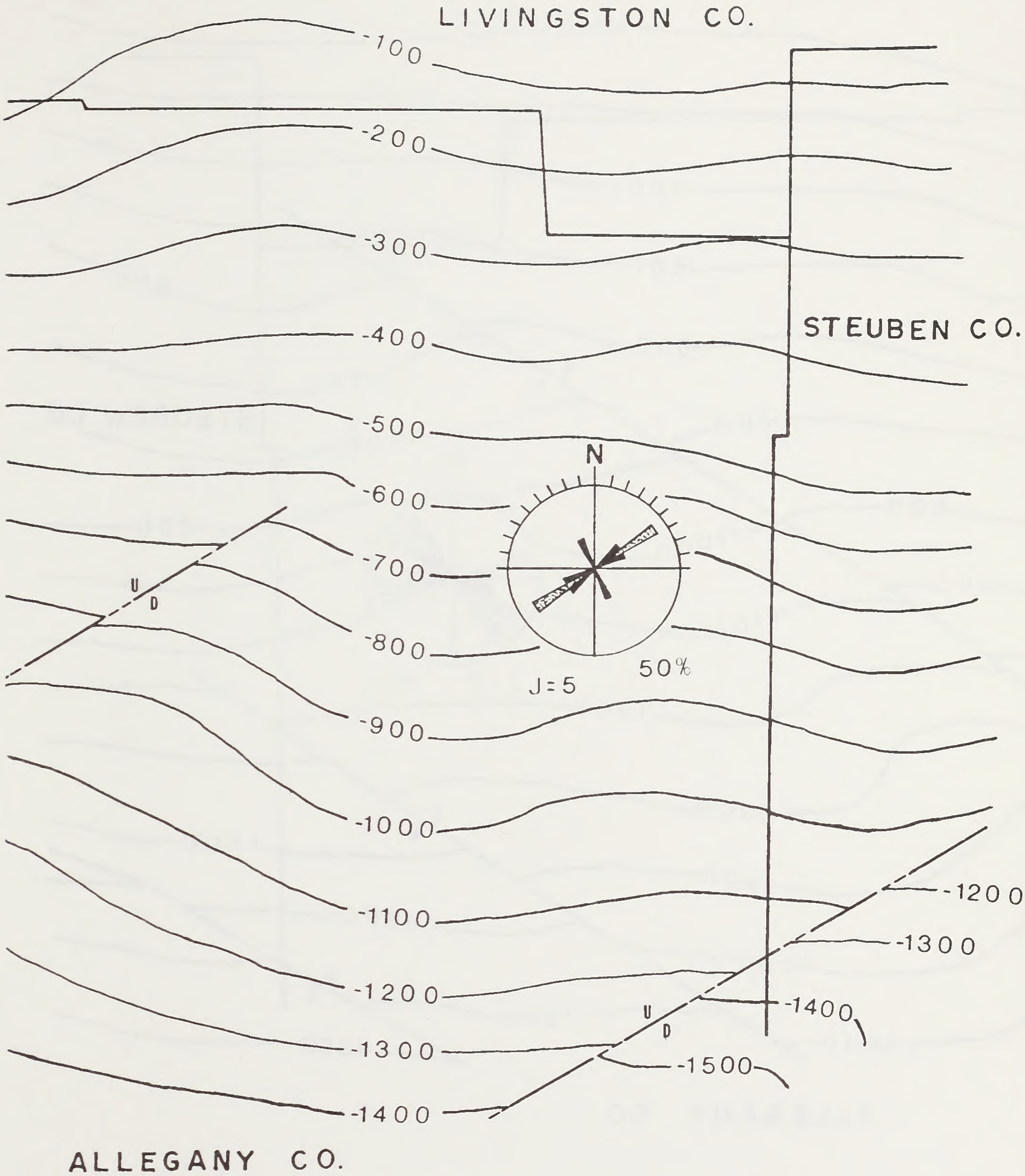


E. G. S. P. NEW YORK - I

STRUCTURAL CONTOURS BASE OF WEST FALLS FORMATION

FIGURE 1D

SCALE 1:250,000

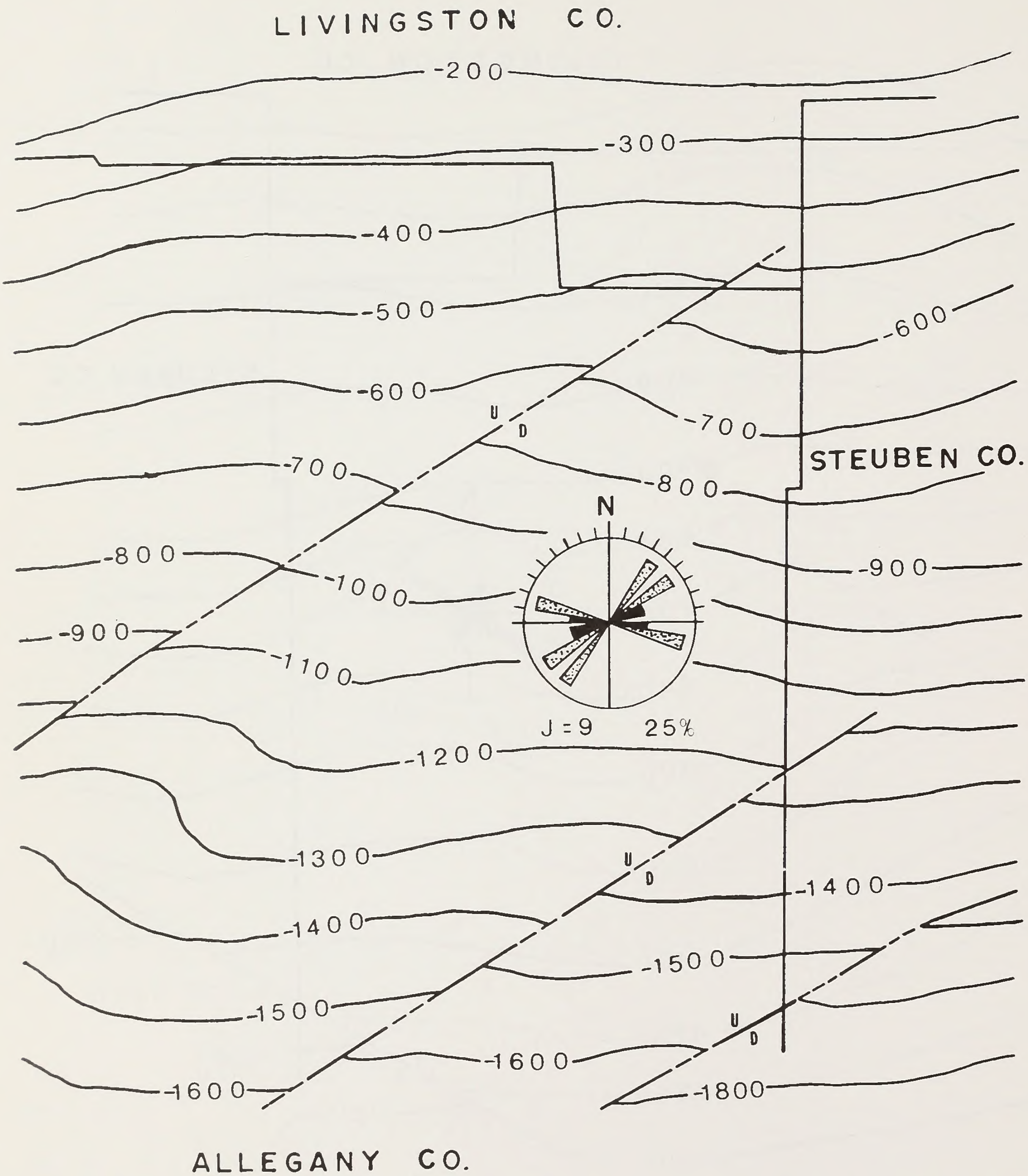


E. G. S. P. NEW YORK- I

STRUCTURAL CONTOURS BASE OF SONYEA FORMATION

FIGURE 1E

SCALE 1:250,000

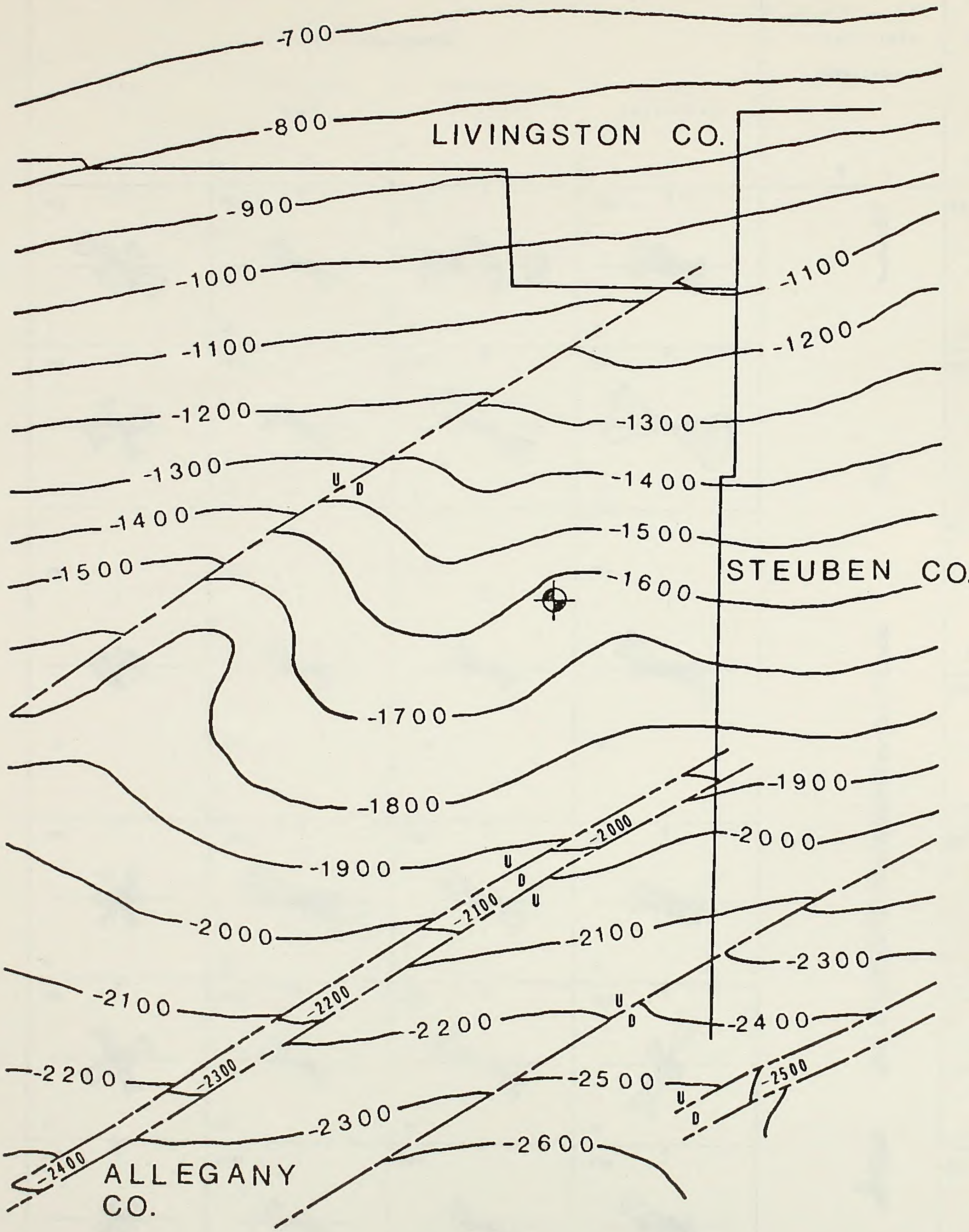


E. G. S. P. NEW YORK - I

STRUCTURAL CONTOURS BASE OF GENESEE FORMATION

FIGURE 1F

SCALE 1 : 250,000



E. G. S. P. NEW YORK- I

STRUCTURAL CONTOURS BASE OF HAMILTON GROUP

FIGURE 1G

Scale 1:250,000

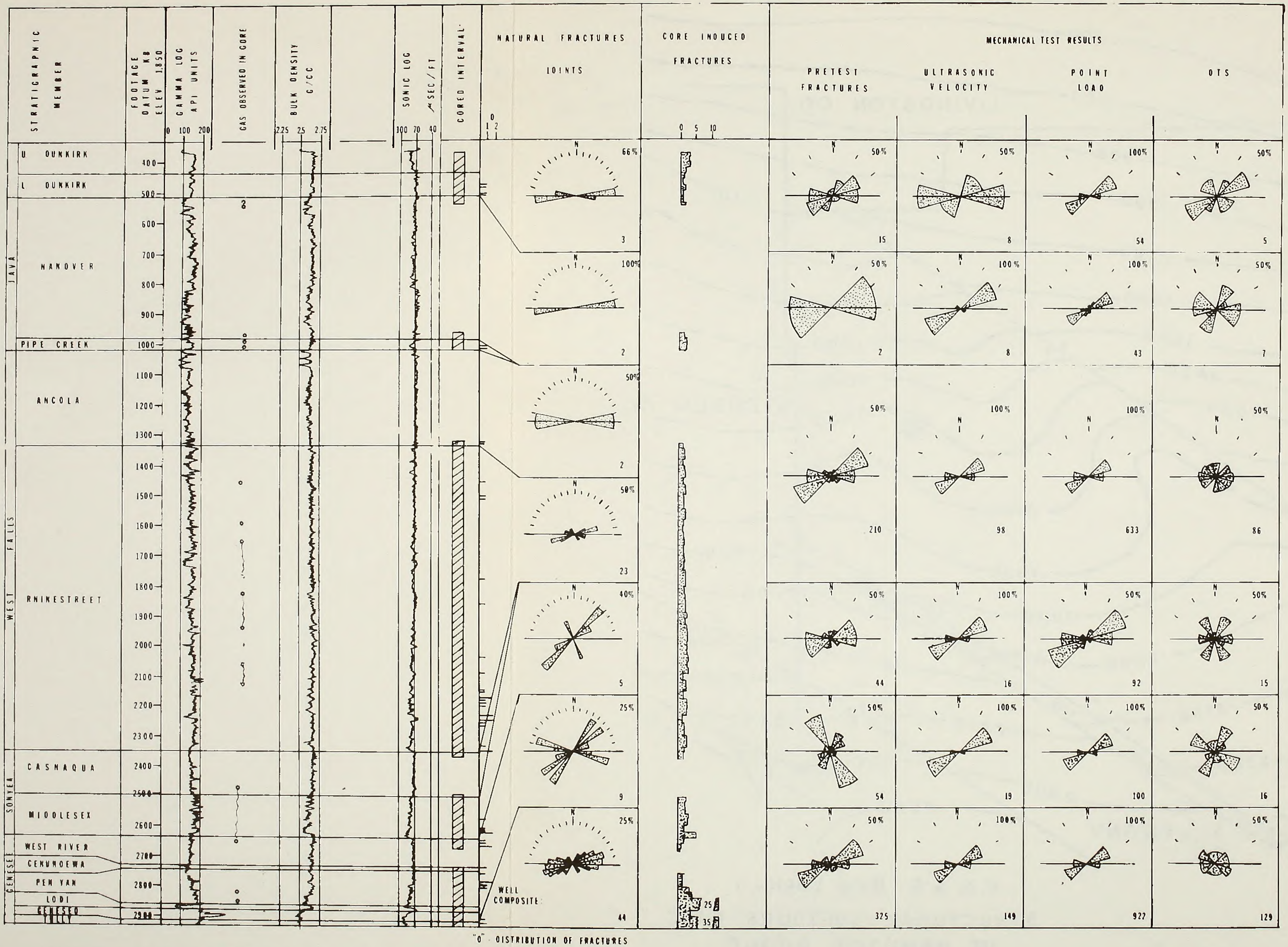


FIGURE 1H EGSP NEW YORK I Well Summary

CLIFFS MINERALS, INC.

EGSP-NEW YORK #3 (AMBROSE E. SCUDDER #1) WELL

LOCATION

The EGSP-New York #3 well is located approximately two miles north and west of the town of Painted Post in Hornby township in southeastern Steuben County, New York. The exact location is 42°11'26"N by 77°04' 59"W at an elevation of +1,503' MSL (Figures 1, 3A and Table 1).

GEOLOGY

The surface topography around the well site consists of rolling hills, and the outcrop in the area is the Devonian West Falls Group. The well is located on the western edge of the Catskill Paleodelta Complex in the northern edge of the Appalachian Basin. The well site is on the south limb of the Alpine Anticline which strikes northeast-southwest and is an extension of the valley and ridge province to the south (Figure 3A).

The New York #3 well was drilled in an attempt to determine whether a fractured zone in the shale would act as a horizontal gas conduit. The well was positioned on a lineament thought to be the surface expression of a deep fault (Donahue, Anstey and Morrill, 1981). The cored interval is in the Rhinestreet Shale from 1,203' to 1,263' (Figure 3C).

PRODUCTION DATA

The well encountered one small gas show at 1,226', the depth of the expected conduit. The core, however, shows little evidence of the reservoir. The well was not stimulated but was left uncased and is now shut in (Donahue, Anstey and Morrill, 1981).

CORING-INDUCED FRACTURES

Other than disc fractures, only nine coring-induced fractures were found in the New York #3 core: six petal fractures, one hook fracture, one torsional fracture, and one disc fracture with circular slickensides due to core rotation in the core barrel. None of the coring-induced fractures could be oriented (Figure 3C).

NATURAL FRACTURES

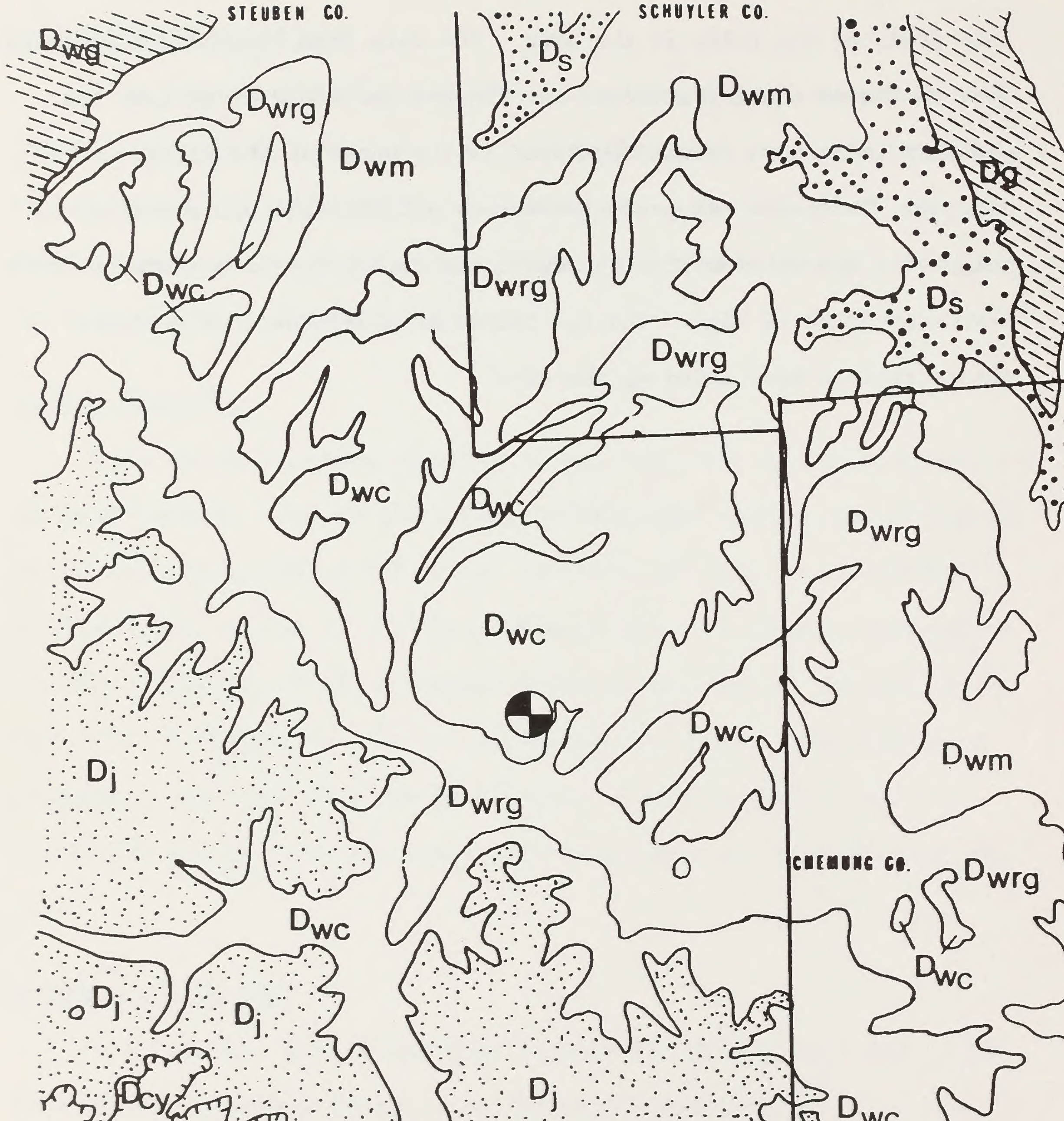
Three vertical joints appeared in the core, all in the area of the expected conduit. All of the joints contain some calcite mineralization. Two of the joints have a N-S strike and are 0.1' long, the third has a N48°E orientation and is 0.5' long (Figure 3C). The joint orientations are shown on a map of the structure drawn on the base of the West Falls Formation in Figure 3B. The N-S joints are associated with a regional systematic joint set that has been mapped on surface by the New York Geological Survey. One microfault striking N58°W was identified in the core.

MECHANICAL TEST DATA

Core from New York #3 was only sampled for point load tests. The five pretest fractures in the core indicate a preferred N-S direction. However, 86% of the 36 point load samples broke between N75°E and N135°E. The orientations of the joints and point load tests are shown on the well summary chart (Figure 3C).

A comparison of natural fracture data and mechanical test results indicates two preferred fracture trends. Both the pretest fracture and joint strikes show a N-S orientation that can be related to the stresses

that produced the folds in the area. The data from the point load tests show an almost equal preference for the E-W and N60°W directions that probably indicate a fabric developed at the onset of the Allegheny Orogeny. The joint and pretest fracture orientations are supported by relatively few data points. However, the percentage of preference for a N-S orientation is high. The two trends indicate that two separate stress regimes have acted on the area.



E.G.S.P. NEW YORK-3 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

Dcy	CANADAWAY Gp.	Devonian
Dj	JAVA Gp.	
Dwc Dwrg Dwm	WEST FALLS Gp.	
Ds	SONYEA Gp.	
Dg	GENESEE Gp.	

SCALE 1 : 250,000

FIGURE 3A

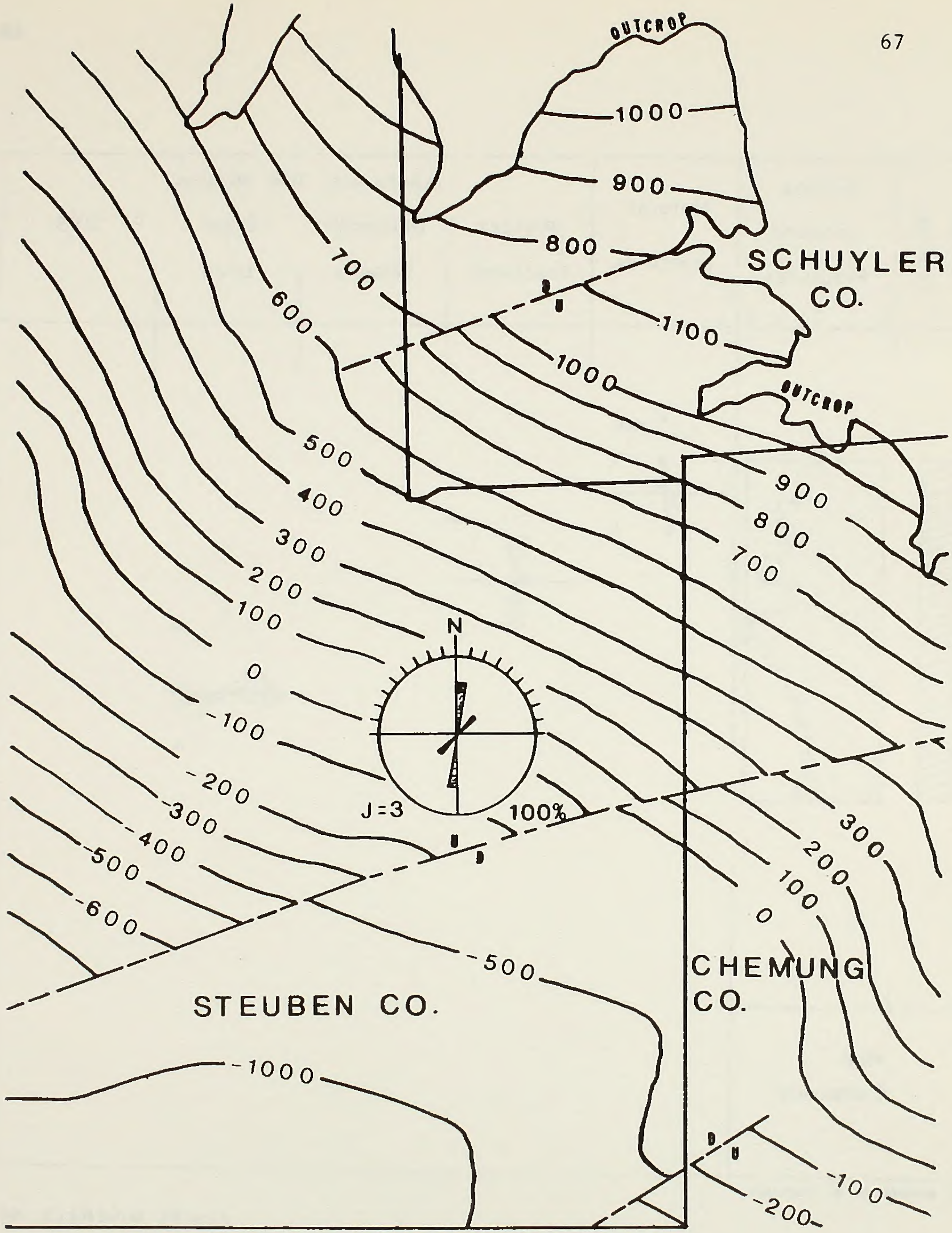


FIGURE 38

E.G.S.P. NEW YORK-3

STRUCTURAL CONTOURS
BASE OF WEST FALLS FM.

Scale- 1:250,000

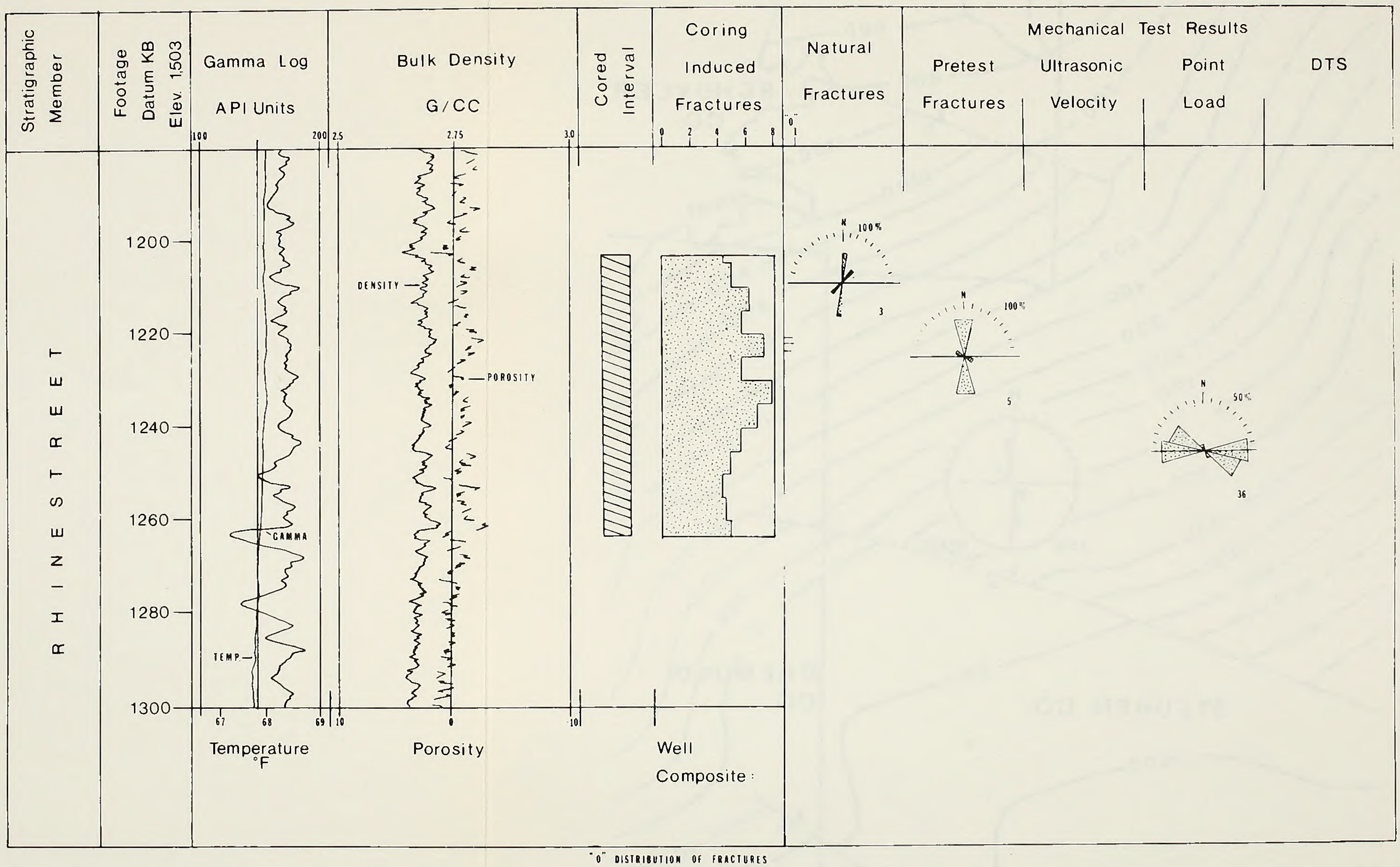


Figure 3C EGSP New York 3 Well Summary

CLIFFS MINERALS, INC.

EGSP-NEW YORK #4 (VALLEY VISTA VIEW #1) WELL

LOCATION

The EGSP-New York #4 well is located approximately 2.5 miles northwest of the town of Rathbone, Rathbone Township in southeastern Steuben County, New York. The well's exact position is 42°09'54"N by 77°23'42"W at an elevation of +1,451' MSL (Figures 1, 4A and Table 1).

GEOLOGY

The well is located on the northern edge of the Appalachian Basin and on the western edge of the Catskill Paleodelta Complex. The outcrop in the area is Upper Devonian Java Group. Initially, the exploration rationale was to revitalize an old gas field in the Rhinestreet Shale. The well was positioned near a suspected subsurface flexure which might be developed as a fractured reservoir. The detailed maps show the well site is bounded by NE trending faults that are probably associated with detachment at a lower level (Figures 4B and 4C). Overall dip of the formations is to the southwest. Two intervals were cored: 3,010'-3,084' in the Geneseo Shale with four feet of Tully Limestone at the base of the core, and 3,790'-3,848' in the Marcellus Shale with six feet of Onondaga Limestone at the base of the core (Figure 4F).

PRODUCTION DATA

Both core intervals bled gas when they were removed from the core tube. The well was stimulated in two intervals, the Rhinestreet and the Marcellus. The Rhinestreet produced little more than water. The Marcellus yielded a sustained open flow of 200 mcf/day with an expected

initial production of 127 mcf/day against a line pressure of 250 psi. The well is currently shut in (Donahue, Anstey and Morrill, 1981).

CORING INDUCED FRACTURES

No petal or petal centerline fractures appeared in the core. Four coring induced torsional fractures were found in a 14-foot interval and are attributed to core jamming in the core barrel. All four fractures have the same orientation and developed between core orientation scribe grooves.

NATURAL FRACTURES

Three joints were seen in the core, one in the Geneseo Shale and two in the Onondaga Limestone. The Geneseo joint is 2.5' long and strikes N50°W. It is associated with a more competent mudstone bed bounded by fissile shale. The Onondaga joints strike N34°E and N70°W, respectively, and are located at the top of the limestone just below the Marcellus Shale contact. All three joints have calcite mineralization. Structure, including joints, drawn on the base of the Rhinestreet Formation is shown in Figures 4B and 4C. The orientation of the respective joints is shown at the well location and seems to be related to the formations' strikes and dips.

Two horizontal faults occur in the Geneseo Shale, seven horizontal and 22 inclined faults occur in the Marcellus Shale, and 13 inclined faults occur in the Onondaga Limestone. Eleven faults in the Marcellus strike N30° to 59°W, with the remaining four bearing N20°-30°W and N60°-70°W. Five faults dip NE from 02° to 75°, eight dip SW from 03° to 45°; the remaining faults dip W04° and S25°. Seventeen of the fault planes

contain calcite mineralization. The Onondaga has eight faults that dip west from 19° to 40°, four that dip SW from 20° to 28°, and one fault that dips south at 12°. Figure 4E is a Schmidt net of the poles to fault planes. The faults also show a relationship to the structure defined in Figures 4B and 4C. The block outlined by the NE faults is parallel to movement on the low angle faults. The contact between the Marcellus Shale and Onondaga Limestone appears to be a detachment with 37 faults occurring in a vertical distance of 40 feet.

Slickensides on the two Geneseo faults strike N40°E and N34°E. Twenty of the faults in the Marcellus have slickensides that may be oriented. Thirteen of the twenty strike from N31°E to N70°E. Of the remaining seven, three strike N01°E to N20°E and four strike N61°E to N80°E. Ten of the thirteen slickenside traces in the Onondaga bear between N41°E and N60°E with one each bearing N32°E, N70°E, and N14°E. The major trends of the slickensides in the Marcellus and Onondaga Formations are approximately perpendicular to the strikes of the faults and parallel to the dip of the bedding planes of the formations. Figure 4E is a Schmidt net of the slickenside orientations and poles to fault planes.

MECHANICAL TEST RESULTS

Pretest fractures are detectable only in the Geneseo Shale. The major trend is N60°W with trends of decreasing magnitude at N30°W, N30°E and E-W.

The point load data for the Geneseo shows a major trend oriented at N60°W and a lesser trend at N30°W. The point load data for the Marcellus Shale shows a major trend at N30°W and a minor trend at N60°W.

The major velocity trend in both the Geneseo and the Marcellus is N30°W. The directional tensile strength testing indicates a preferred fracture direction of N30°W in the Geneseo and N30°E in the Marcellus.

The trend in fabric or weakness planes defined by the test results is N30° to 60°W which disagrees with the general NE trends shown in the other EGSP wells. The difference here may be the control of stresses by the NE fault systems which probably developed early in the deformation if the systems are associated with detachment in the underlying Silurian evaporites.

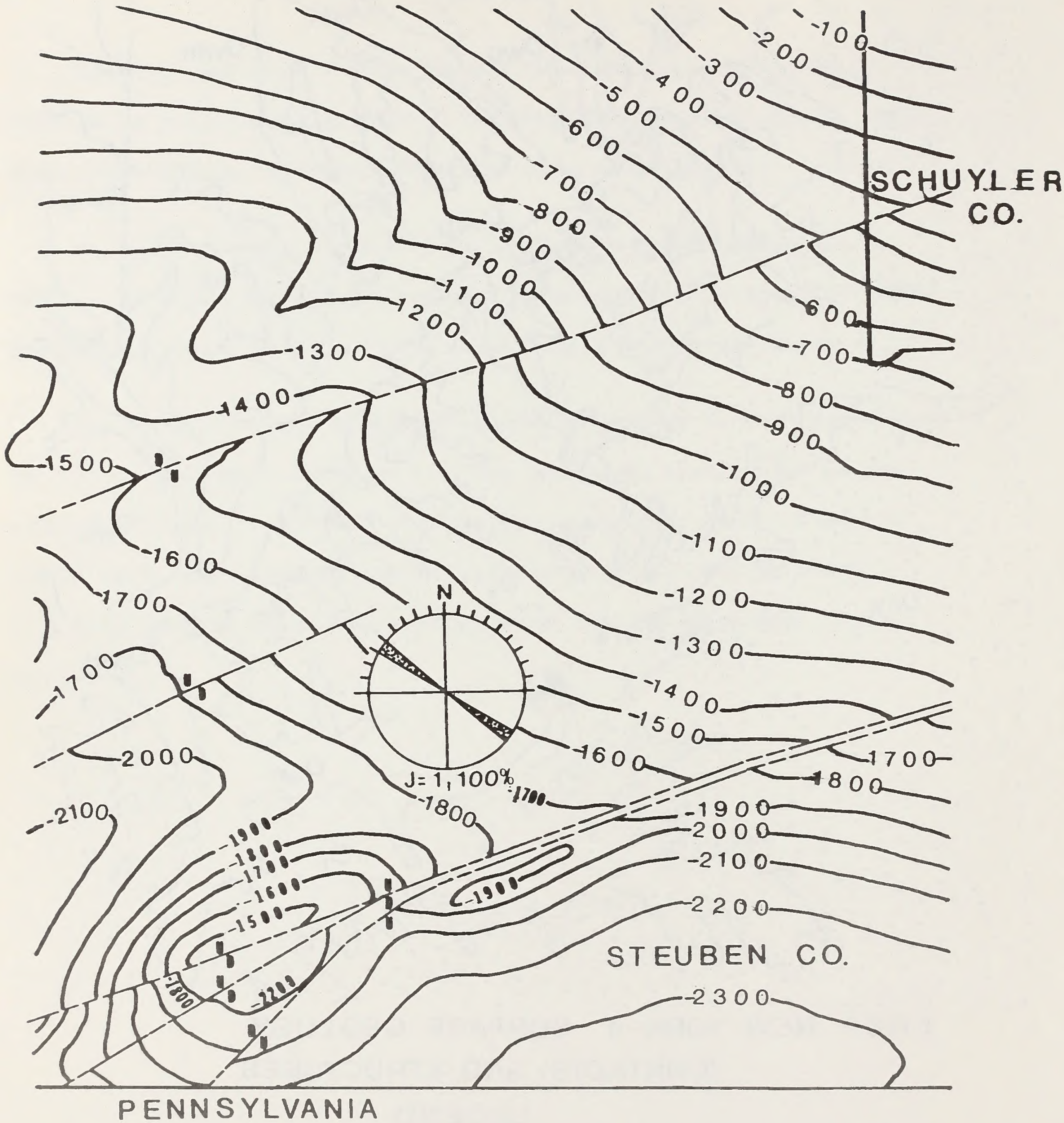
E.G.S.P. NEW YORK-4 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

Dcy	CANADAWAY Gp.	Devonian
Dj	JAVA Gp.	Devonian
Dwc Dwrg Dwn Dwm Dwg	WEST FALLS Gp.	Devonian

SCALE 1 : 250,000

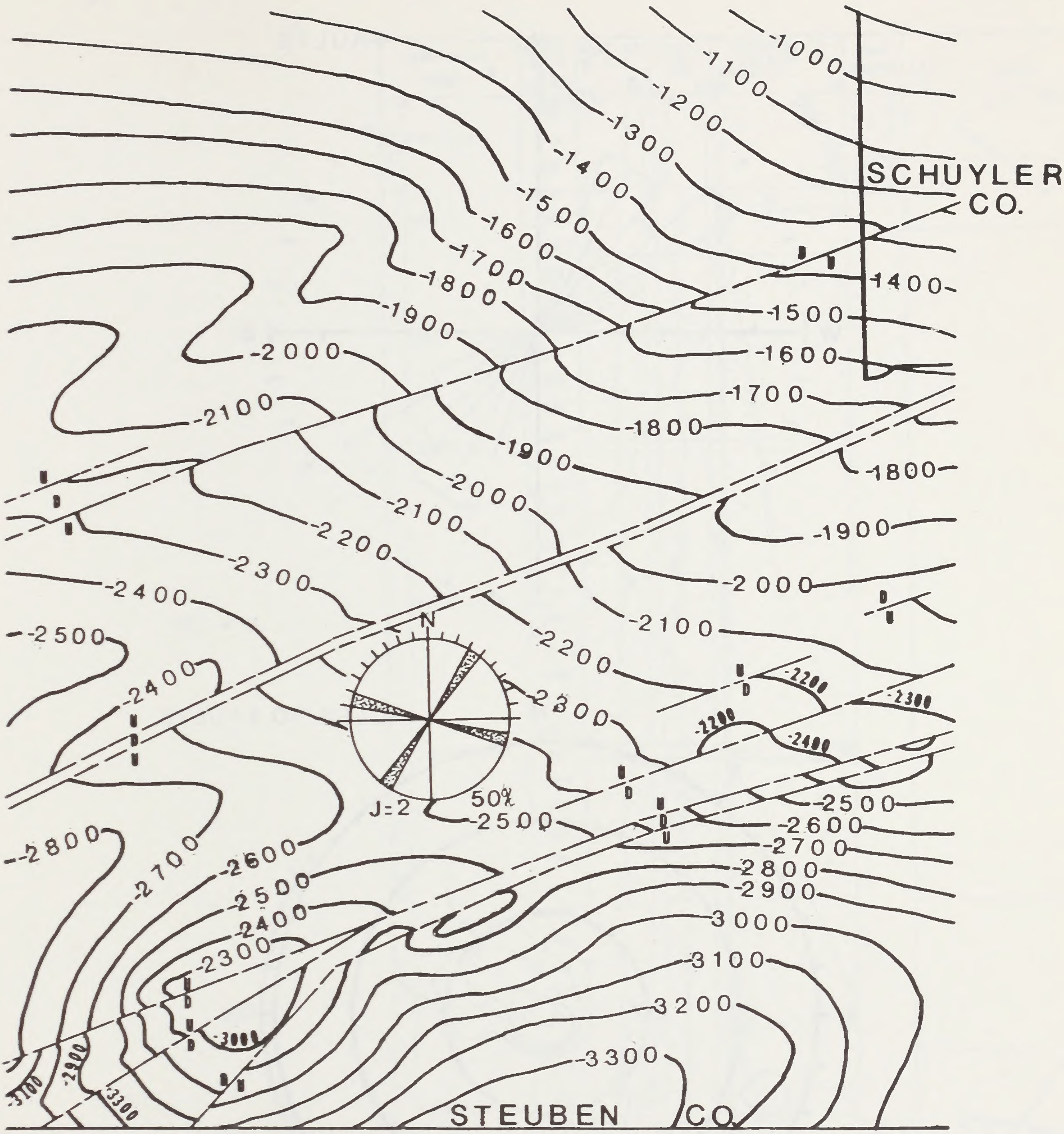
FIGURE 4A



E.G.S.P. NEW YORK-4

STRUCTURE CONTOURS
BASE OF GENESEE FM.
FIGURE 4B

Scale- 1:250,000

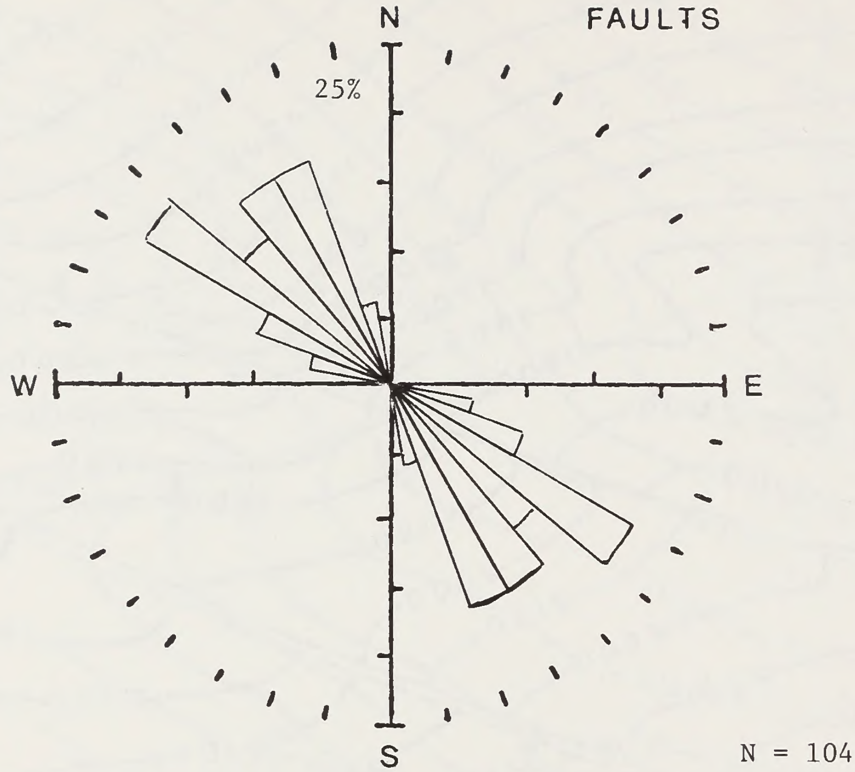


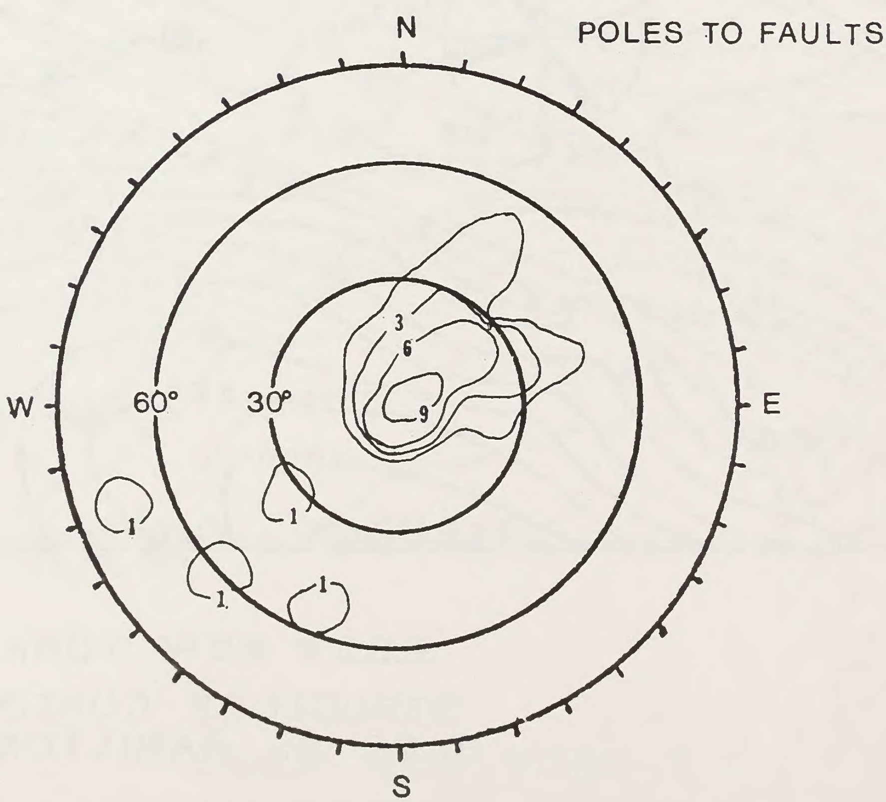
E.G.S.P. NEW YORK - 4

STRUCTURE CONTOURS
BASE OF HAMILTON GROUP

Scale 1:250,000

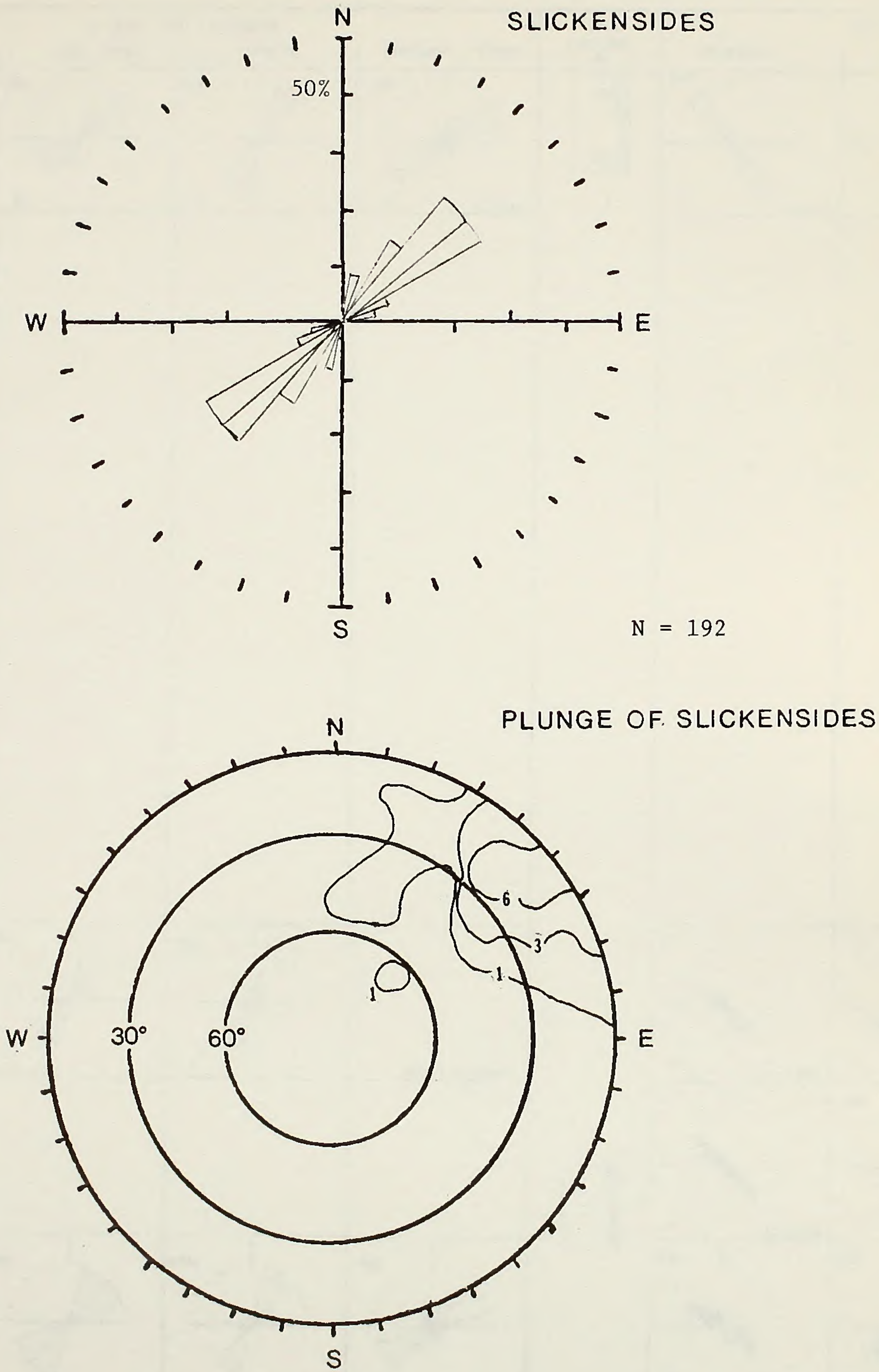
FIGURE 4C





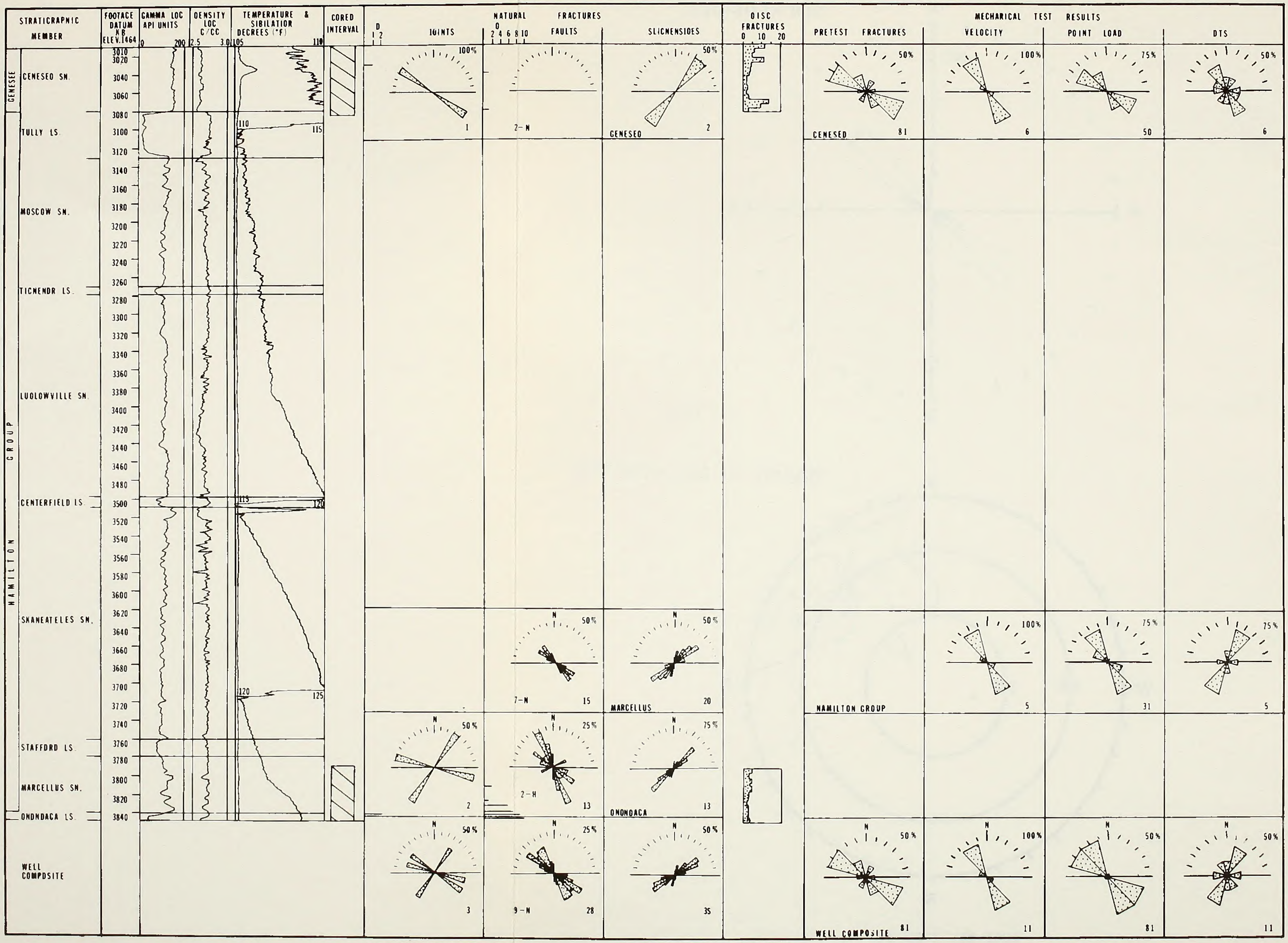
EGSP-NEW YORK #4

Figure 4D. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.



EGSP-NEW YORK #4

Figure 4E. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.



"D": DISTRIBUTION OF FRACTURES
"H": HORIZONTAL

FIGURE 4F E.G.S.P. NEW YORK 4 WELL SUMMARY

APPENDIX C

OHIO EGSP WELLS

OHIO #1:	(GLEN-GERY #5-745) WELL
OHIO #2:	(HOUSE #R-109) WELL
OHIO #3:	(BECKHOLT #1) WELL
OHIO #4:	(MONSANTO RESEARCH CORP.) WELL
OHIO #5:	(McGUIRE #20149-T) WELL
OHIO #6-1:	(CARPENTER #1-5) WELL
OHIO #6-2:	(WHITE UNIT #1-7) WELL
OHIO #6-3:	(McCOMB #1-6) WELL
OHIO #6-4:	(STRAIGHT UNIT #1-8) WELL
OHIO #6-5:	(CARTER #1-9) WELL
OHIO #7:	(COLUMBIA GAS #20143-T) WELL
OHIO #8:	(SCHOCKLING #1) WELL
OHIO #9:	(COLUMBIA GAS #10056A) WELL

EGSP-OHIO #1 (GLEN-GERY #5-745) WELL

LOCATION*[1]

The EGSP-Ohio #1 well is located in western Carroll County, Ohio, ten miles southeast of the city of Canton (Figures 1, 1A and Table 1).

GEOLOGY

The well is located in an area underlain by Upper Pennsylvanian sediments of the Conemaugh Formation. Major geologic structures include a large NW trending fault system to the NE which displays vertical displacement downward on the south side and the Cambridge Arch to the west which shows a significant change in surface structural attitude between the Onondaga Limestone and the Berea Sandstone (Figures 1B and 1C). The block outlined by the above structures is also apparent on the geology map of Ohio, 1981. Distinct changes in the strike of bedding in the Upper Devonian through Permian sediments across these structures indicate a deformation large enough to generate fractures in the Devonian Shales. More detailed work is suggested in this area.

The cored sections total 240' from the intervals 2,080'-2,200' in the Upper Huron Shale and 3,080'-3,200' in the Rhinestreet Shale and Upper Hamilton Group* (Figure 1D).

PRODUCTION DATA*[2]

No production data was available from this well.

FRACTURE ANALYSIS*[3]

The core was oriented by Morgantown Energy Technology Center personnel with no distinction being made between coring-induced fractures,

natural fractures, and slickensided fractures. In this study, all fractures are undifferentiated. Fracture strikes were measured, but no fractures dips (Byrer and Rhoades, 1976).

The composite rose diagram of undifferentiated fracture strikes (Figure 1D) has a single statistically significant peak at N25°E. There is a 5.0% chance that this peak does not exist. A smaller peak which is not statistically significant occurs at N63°W. Fracture orientations are widely variable (between stratigraphic members). Fracture sets are distinct in the Upper Huron Member of the Ohio Shale but are more scattered and less distinct in the West Falls Formation. Due to the fact that neither fracture types nor dips are known, no reliable interpretations can be made.

Surface structure maps drawn on top of the Berea Sandstone and on the Onondaga Limestone (Figures 1A and 1B) both show a change in strike at the well site that parallels the orientation of the fractures in the core. Therefore, it is likely the fracturing is associated with the structure west of the well site and the stress system associated with that structure. The stress system appears to be a tensional stress normal to the fracture strike on the east limb of the south-plunging anticlinal fold.

MECHANICAL TEST RESULTS

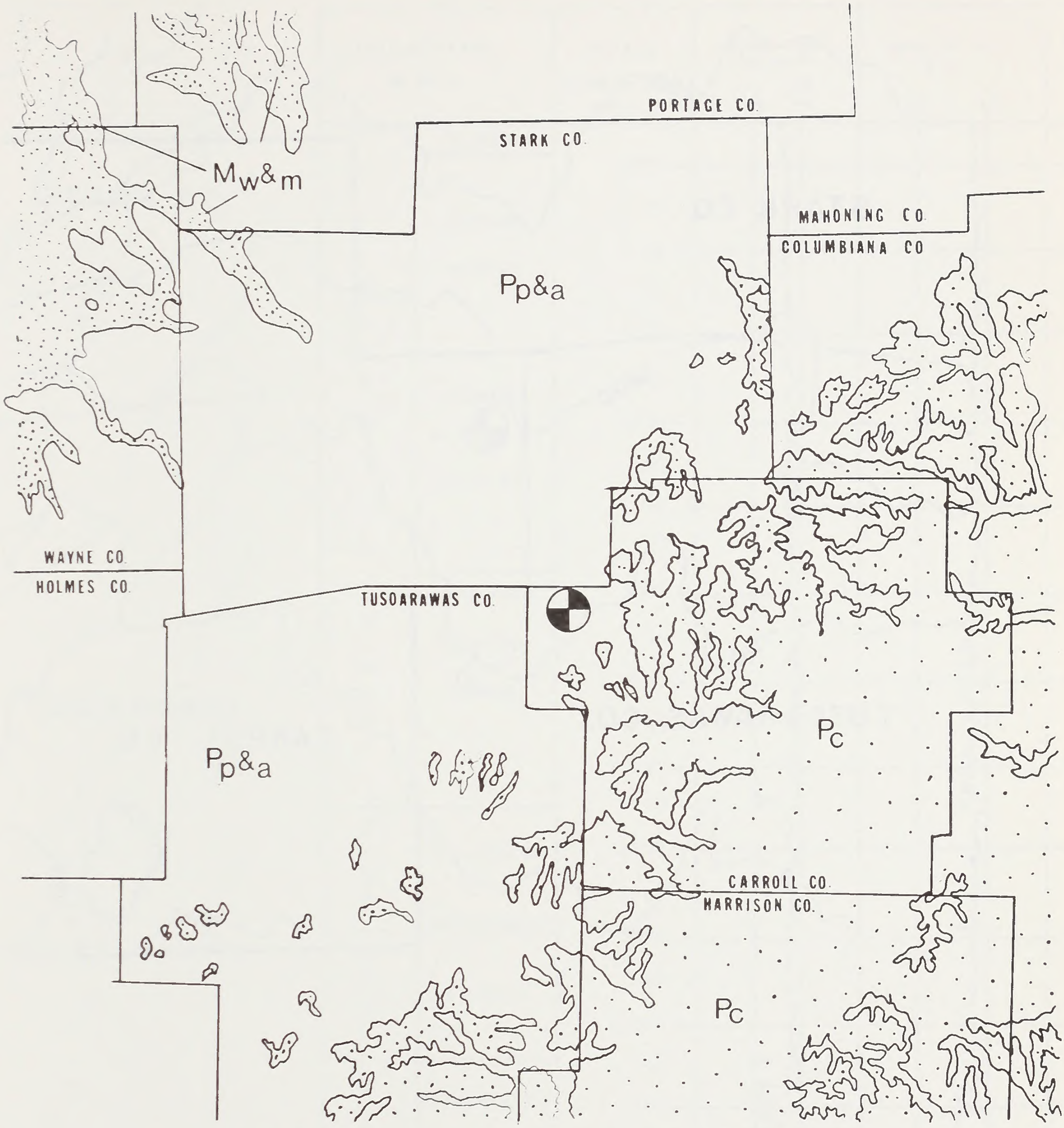
The mechanical testing for Ohio #1 was done at the Morgantown Energy Research Center in 1975. Plane of weakness trends defined by the test results vary widely. The only correlation that can be made is a N30°E trend in the summation of well composites that parallels the

undifferentiated fracture trend. A better explanation may be that the fractures are coring induced and the variability between stratigraphic members represents changes in horizontal stress directions.

*[1] p. 178

*[2] p. 178

*[3] p. 178-179.



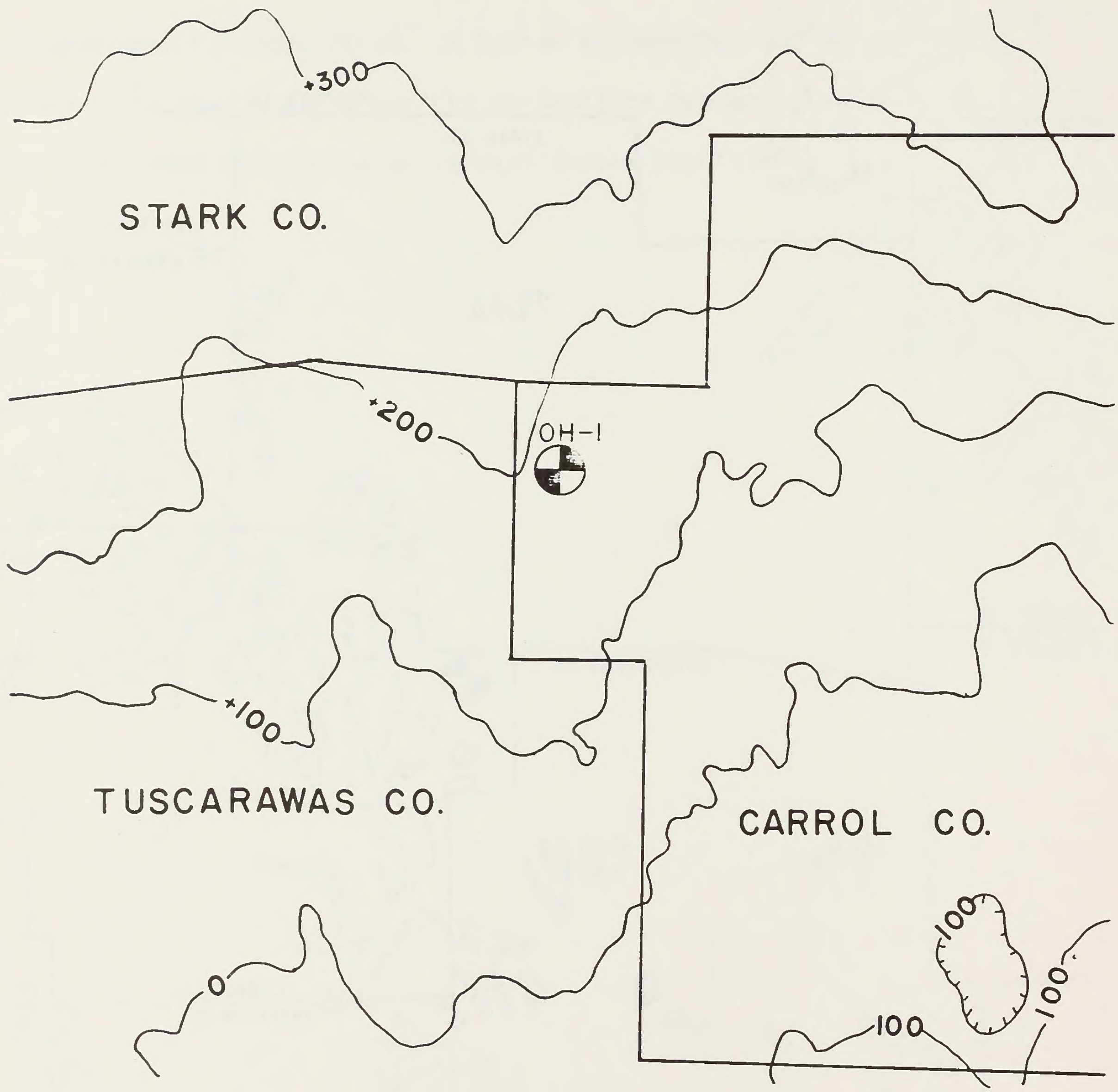
EGSP OHIO-1 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

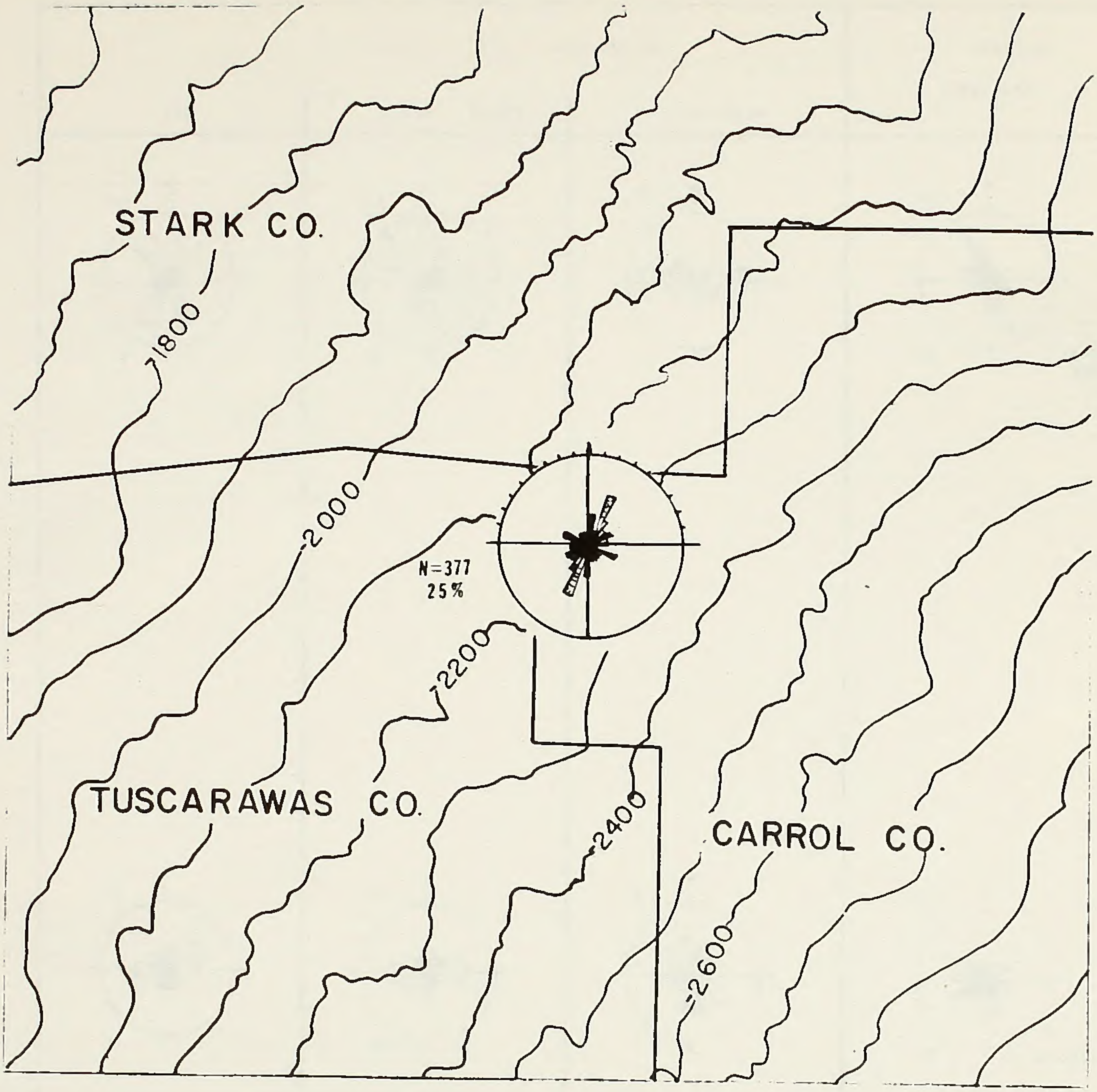
Pc	Conemaugh	Pennsylvanian
Pp&a	Pottsville & Allegheny	Pennsylvanian
Mw&m	Waverly & Maxville	Mississippian

SCALE 1:500000

FIGURE 1A



EGSP OHIO-1
STRUCTURAL CONTOURS
TOP OF BEREA SANDSTONE
Scale 1:250,000
FIGURE 1B



EGSP OHIO-I
STRUCTURAL CONTOURS
TOP OF ONONDAGA LIMESTONE
Scale 1:250,000
FIGURE 1C

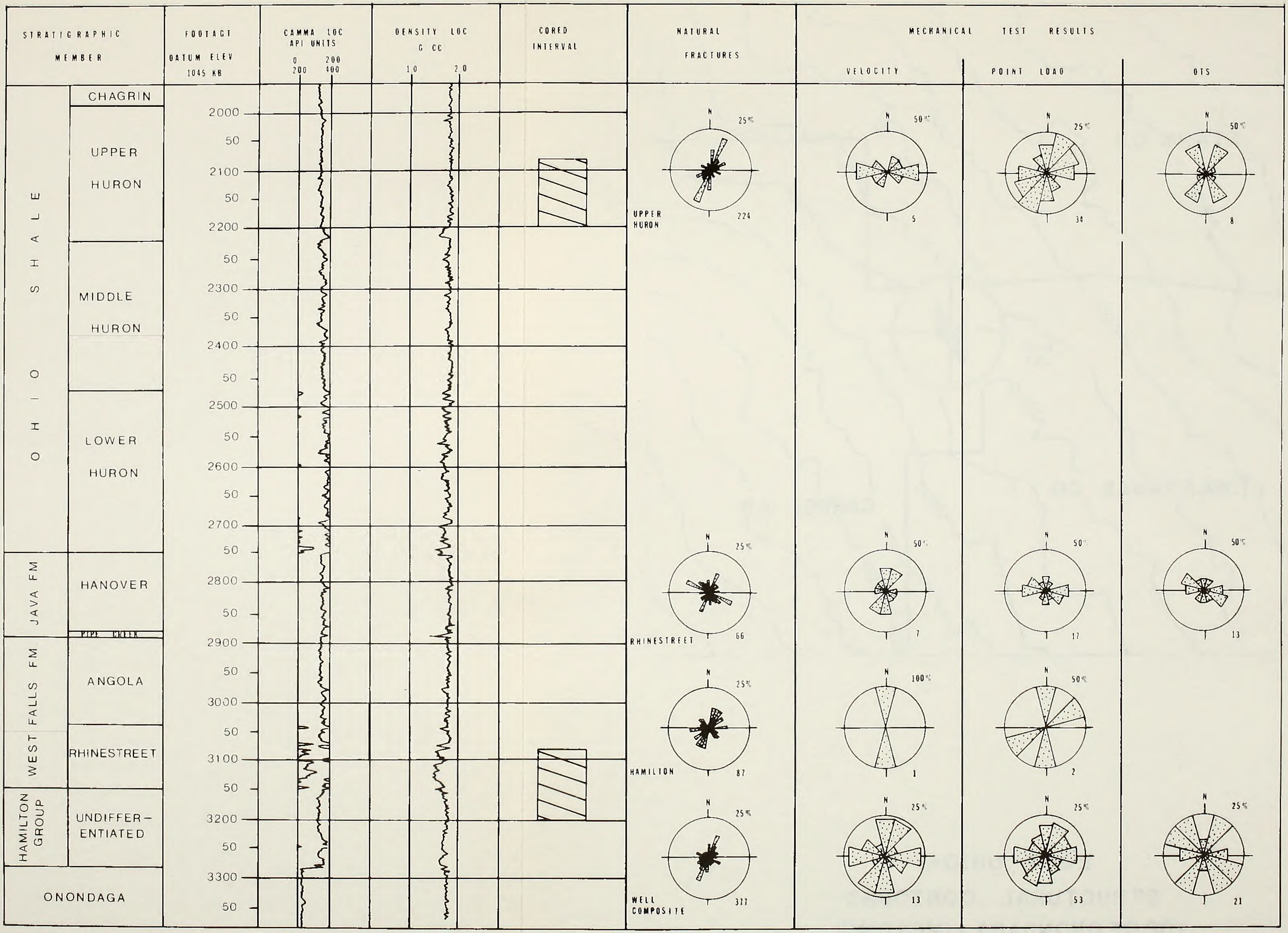


FIGURE 10 EGSP OHIO 1 WELL SUMMARY

EGSP-OHIO #2 (HOUSE #R-109) WELL

LOCATION

The EGSP-Ohio #2 well site is located in south central Washington County, Ohio, approximately two miles northwest of the Ohio River (Figures 1, 2A, and Table 1).

GEOLOGY

The well is located on the north end of the Huntington-Parkersburg Basin and due west of the Burning Springs Anticline. Surface outcrop is composed of Permian Age Dunkard Group sediments (Figure 2A). Structure contour maps drawn on top of the Berea Sandstone and Onondaga Limestone (Figures 2B and 2C) show a significant change in strike of the stratigraphic members just east of the well site. The cored interval from 3,490' to 3,714' occurs within the Lower Huron Shale Member of the Ohio Shale.

PRODUCTION DATA*[1]

No production data was available for this well.

FRACTURE ANALYSIS*[2]

Core fracture orientations were measured by West Virginia Geologic and Economic Survey personnel with no distinction being made between coring induced fractures, natural fractures, and slickensided fractures. In this study the fractures are undifferentiated. According to Vickers (1977, unpublished manuscript) most of the fractures logged in the core are coring induced. He also states that slickensides are abundant below 3,580' with none found above that point.

The rose diagram of undifferentiated fracture strikes (Figure 2E) has one statistically significant peak at N60°-75°E with an average strike of N65°E. There is a 1.0% chance that this peak does not exist. A very minor peak, which is not statistically significant, occurs at N20°W. Fractures in this set are found only in the interval 3,574'-3,601'. The equal area projection of poles to undifferentiated fracture surfaces (Figure 2D) has eight clusters: four corresponding to the inclined and vertical fractures of the N60°-75°E set and four corresponding to the inclined and vertical fractures of the N20°W set. Fracture orientations are widely scattered in the interval 3,490'-3,517' but are very consistent throughout the rest of the core. The consistent fracture orientations suggest the presence of a stress or rock fabric anisotropy. The dominant N60°-75°E strike may be related to the stress that formed the NW trending structure that outlines the change in strike of the Berea Sandstone in Figure 2B. The N20°W set may be an anomalous coring induced fracture set caused by differential stresses in that particular interval, or possibly a natural fracture set composed of tensile fractures which formed parallel to the axis of the plunging anticlinal structure shown in Figure 2B. The difference in strike between the Berea and Onondaga Formations (Figures 2B and 2C) indicates detachment in the Devonian Shale section west of the Burning Springs Anticline.

MECHANICAL TEST RESULTS

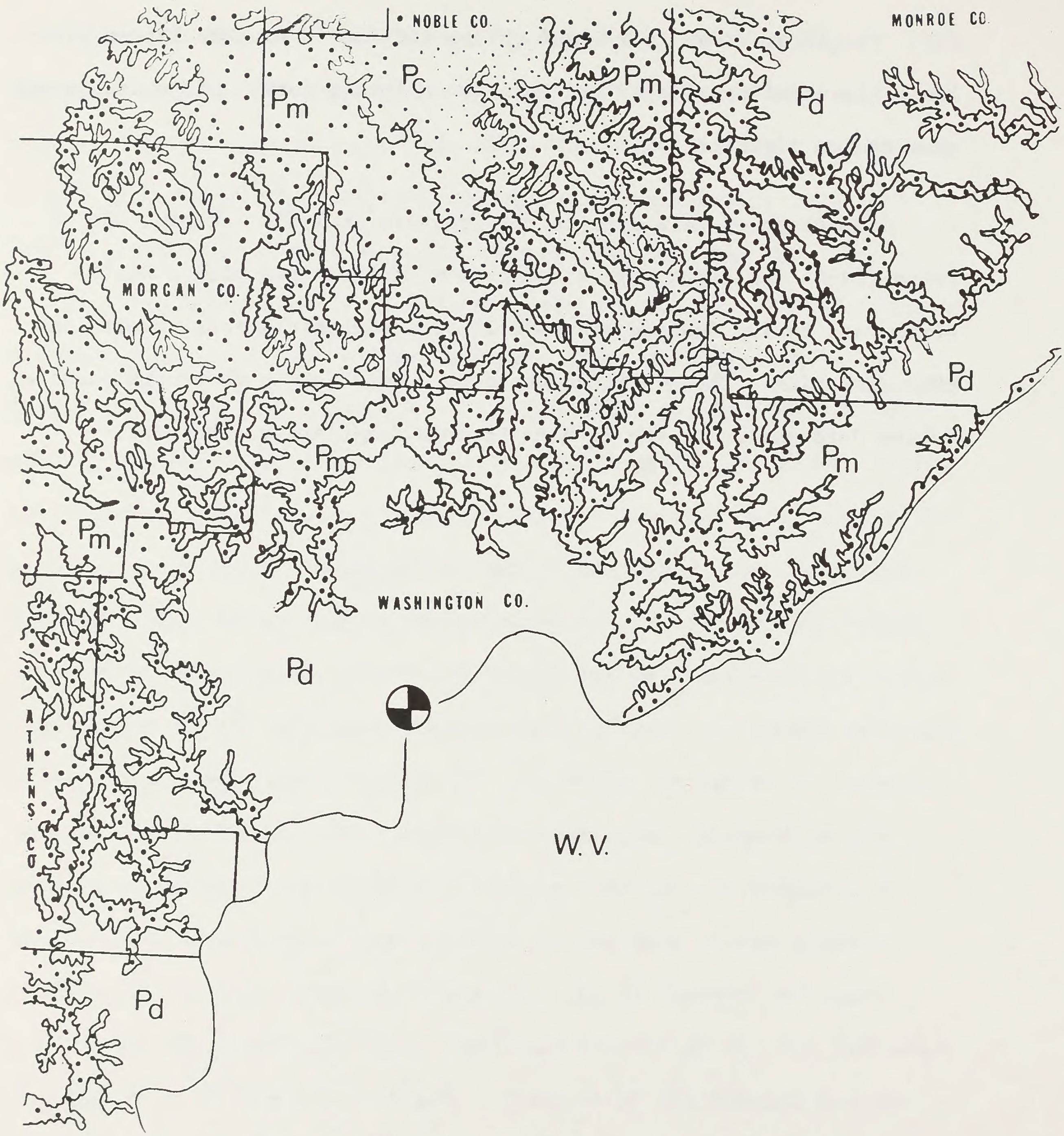
The mechanical tests on the core were run by the Morgantown Energy Research Center's personnel in 1976. Analysis of the test results shows two trends developed in the velocity and point load data (Figure

2F). The first trend is N-S and the second is N60°E. The latter parallels the undifferentiated fracture trend in the core. DTS measurements show random distribution.

Comparison of this data to the fracture analysis descriptions of Evans (1980) indicates that the majority of fractures with a N65°E strike are coring induced and parallel the mechanical test results in that direction. The N-S trend could be a rock fabric developed parallel to the deformation of the Burning Springs Anticline to the east.

*[1] p. 186

*[2] p. 186, 187.



E.G.S.P. OHIO-2 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

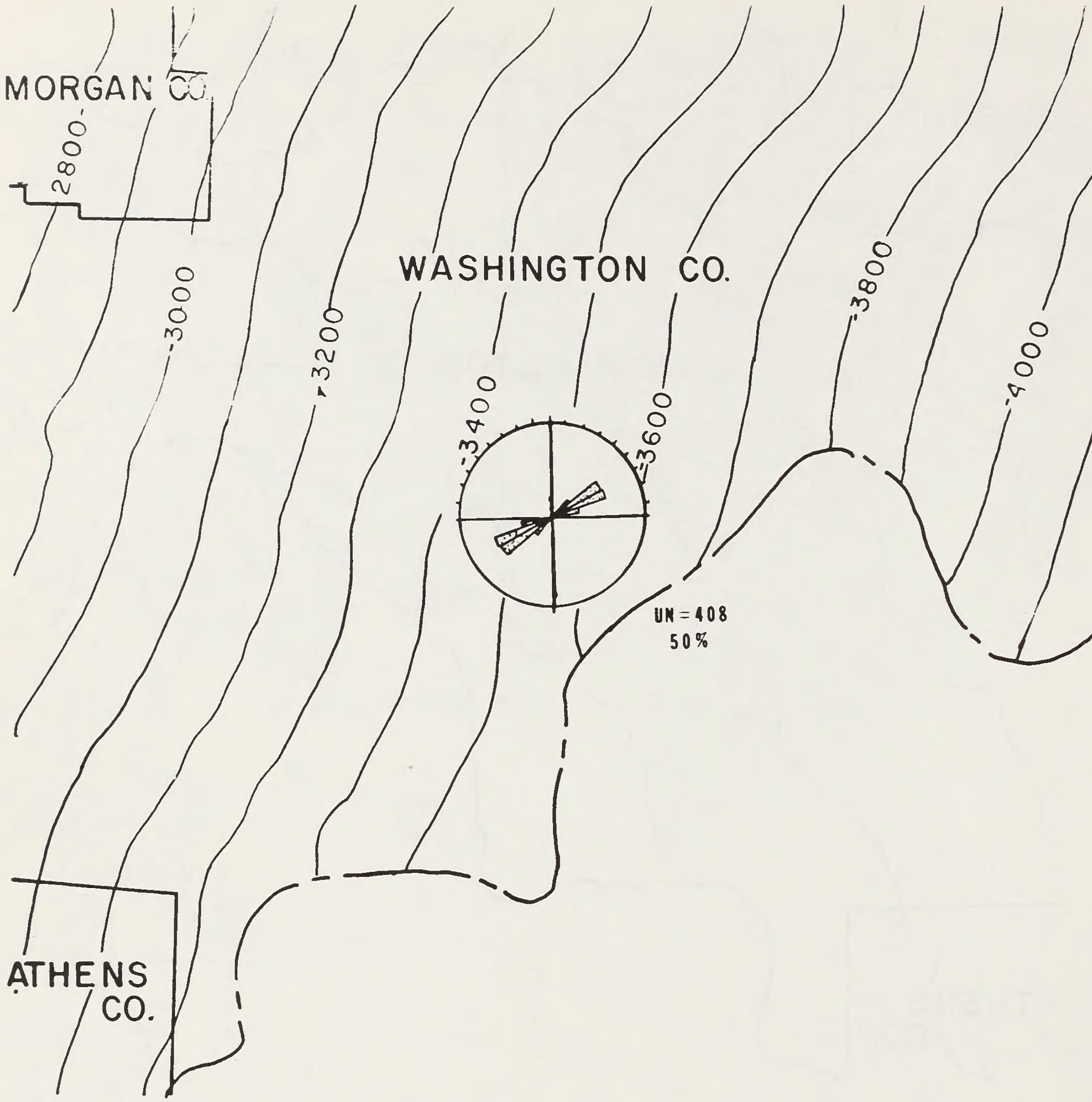
LEGEND

Pd	DUNKARD	Permian
Pm	MONONGAHELA	Pennsylvanian
Pc	CONEMAUGH	

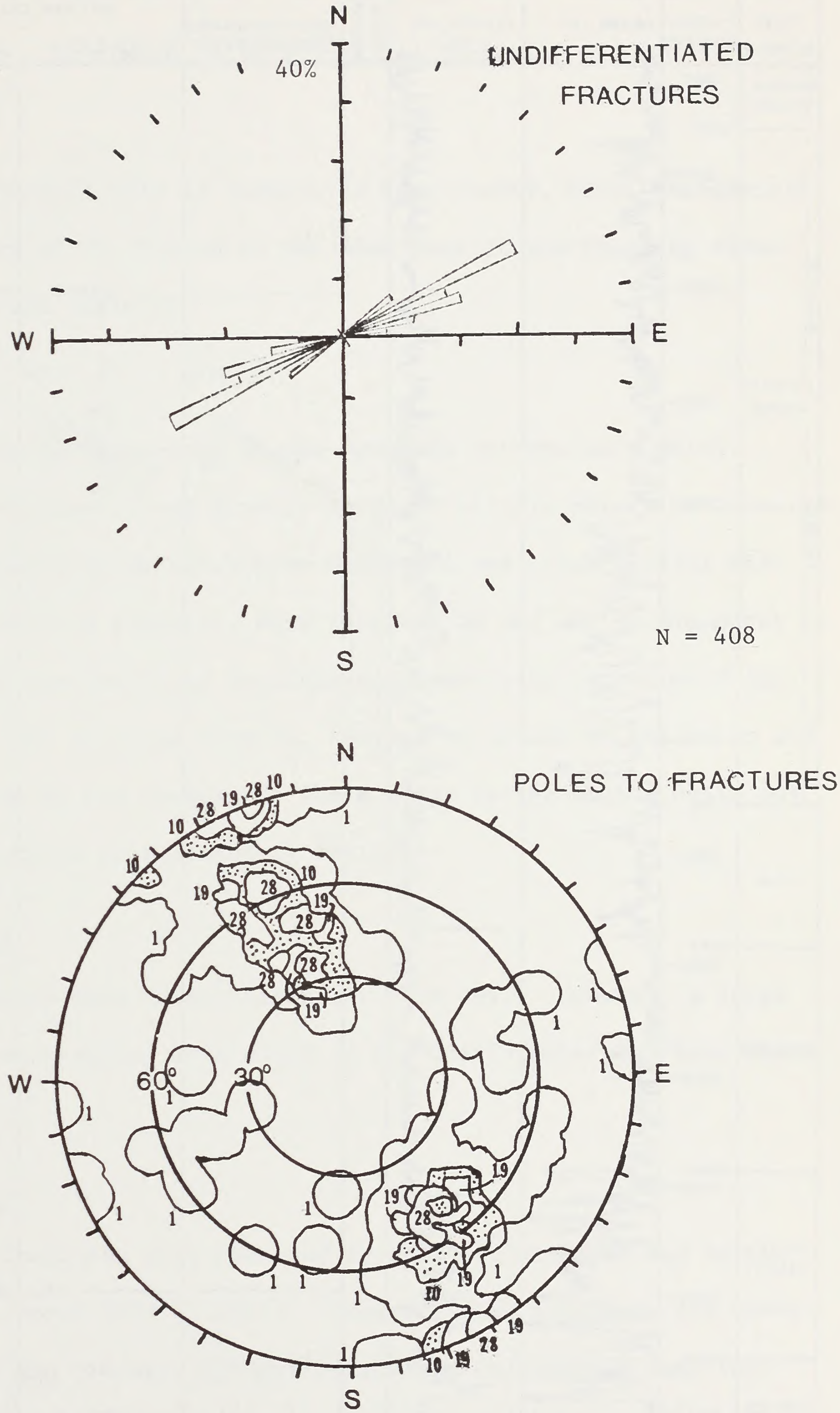
SCALE 1:500,000

FIGURE 2A

EGSP OHIO-2
STRUCTURAL CONTOURS
TOP OF BEREA SANDSTONE
Scale 1:250,000
FIGURE 2B



EGSP OHIO-2
STRUCTURAL CONTOURS
TOP OF ONONDAGA LIMESTONE
Scale 1:250,000
FIGURE 2C



EGSP-OHIO #2

Figure 2D. Composite Rose Diagram of Undifferentiated Fracture Strikes and Equal Area Projection of Poles to Undifferentiated Fracture Surfaces.

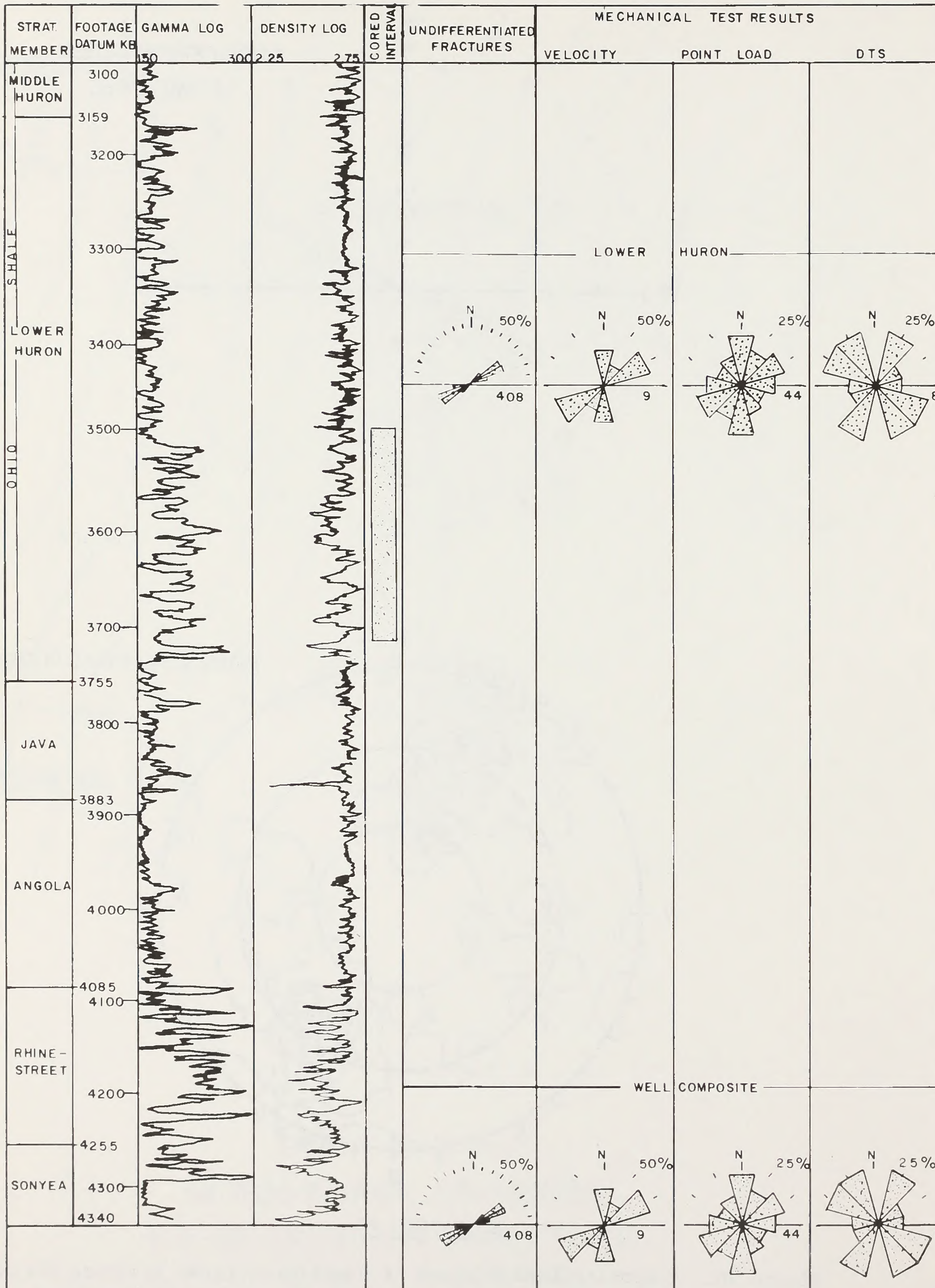


FIGURE 2E EGSP OHIO 2 WELL SUMMARY

CLIFFS MINERALS INC.

EGSP-OHIO #3 (BECKHOLT #1) WELL

LOCATION

The EGSP-Ohio #3 well is located in Knox County, Ohio, immediately west of the city of Mt. Vernon on the west bank of the Kokosing River (Figures 1, 3A and Table 1).

GEOLOGY

The site is 40 miles east of the Devonian outcrop belt which parallels the Cincinnati and Findley arches. At this point the Devonian Shales are overlain by Mississippian sediments and thick glacial till (Figure 3A). Surface structure maps (Figures 3B and 3C) show a north to N10°E strike of the Berea and Onondaga sediments with an eastward dip. Undulations in the surfaces show NE, E-W and SW trends on the Berea and E-W to SW trends on the Onondaga. These warps in the mapped units may be either structural or sedimentary features.

PRODUCTION DATA

No production data is available for this well. However, a large number of gas occurrences were noted in the Cliffs Minerals, Inc. Phase I Report.

PETAL FRACTURES

No petal fractures were observed in the core probably due to the shallow depths cored (562'-1,257'). However, disc fractures are numerous throughout and probably reflect overburden unloading. Some torsional fractures are also present.

NATURAL FRACTURES

Joints:

Only five natural fractures occur in the core. Two joints, bearing E-W and N10°-20°W, are noted in the Chagrin Shale. The other three joints, with a N50°-70°E trend, are in the Huron Shale. They are mineralized with dolomite, calcite and pyrite (Figure 3E).

Faults and Slickensides:

Only one horizontal fault was observed in the lower section of the Middle Huron. Two smaller microfaults on the edge of a limey concretion were also noted and have the same general strike on their slickensides denoting some movement SW to NE.

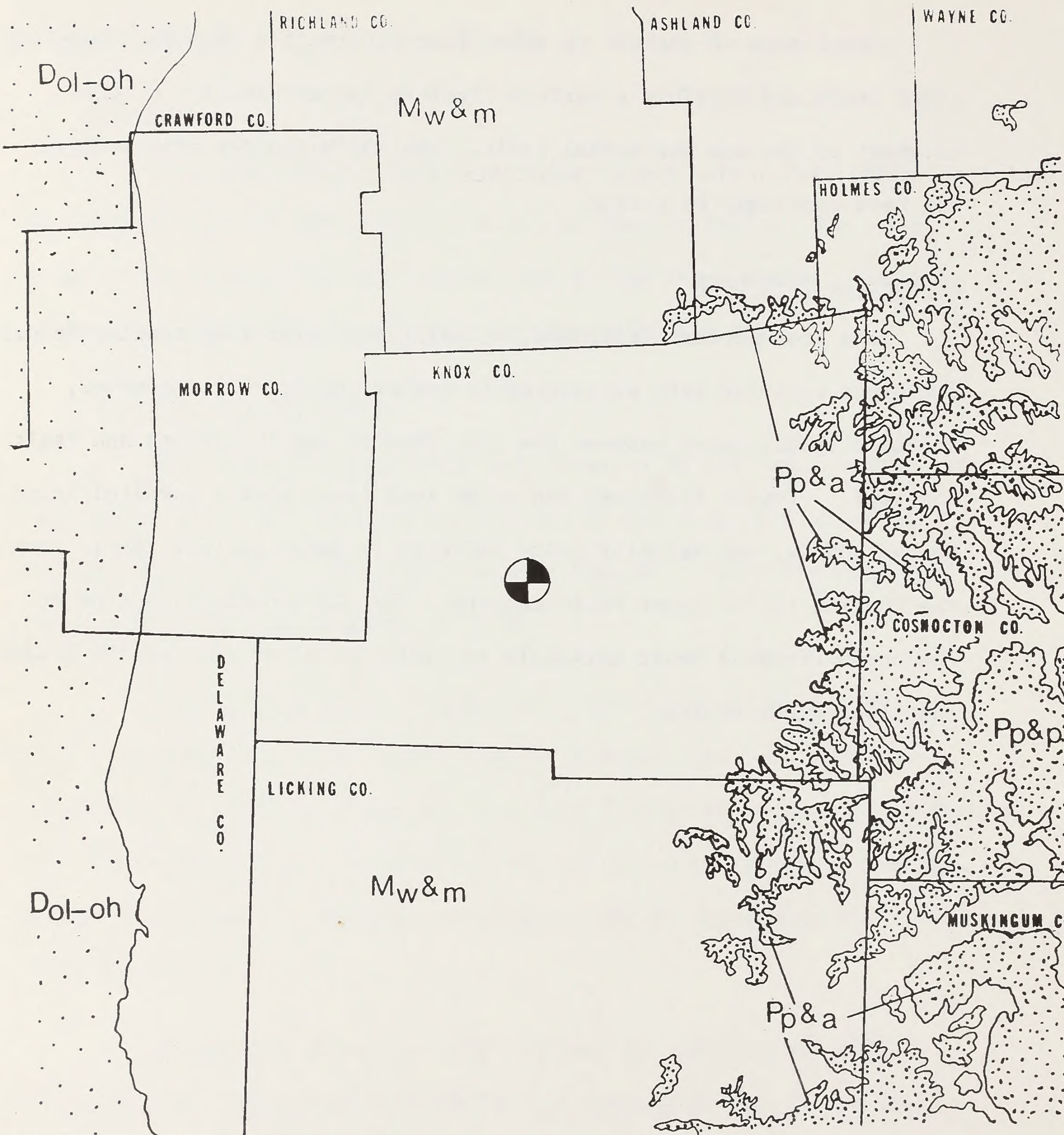
A lack of natural fractures and faults are evident in this well. The N50°-70°E joint trend does not parallel the only observed slickenside direction and appears to result from deformation that differs from that which formed the fault. Arrest lines on these joints indicate propagation from SW to NE which could be caused by a buttress effect of the Cincinnati Arch.

Information compiled under Contract No. DE-AC21-78MC08386, "Devonian Shale Extraction Test Wells" (Thurlow Weed Assoc.) has been interpreted as follows: Landsat lineaments determined at the well site show a variety of orientations with major trends N70°-80°W and N30°W, and two lesser trends N55°-65°E and N70°-80°E (Figure 3D). Fractures compiled by air photo and surface interpretations indicate major trends N-S and N50°-60°E with lesser trends E-W and N30°-40°W.

Comparisons of surface to subsurface information show the N50°-70°E joint trend and possibly a surface fracture system parallel to the movement on the one horizontal fault. The N30°W and E-W systems have not been confirmed by coring.

MECHANICAL TEST DATA

Data from pretest fractures, velocity and point load testing do not correlate well for each stratigraphic member (Figure 3E). However, definite trends exist between the test results and the joints and fault observed. Pretest fractures and point load tests show a parallel trend to the joints, and velocity tests indicate a change in rock fabric from the Chagrin to the lower shale members. The slickenside direction on the one horizontal fault parallels the velocity direction for the Middle and Lower Huron Shales.



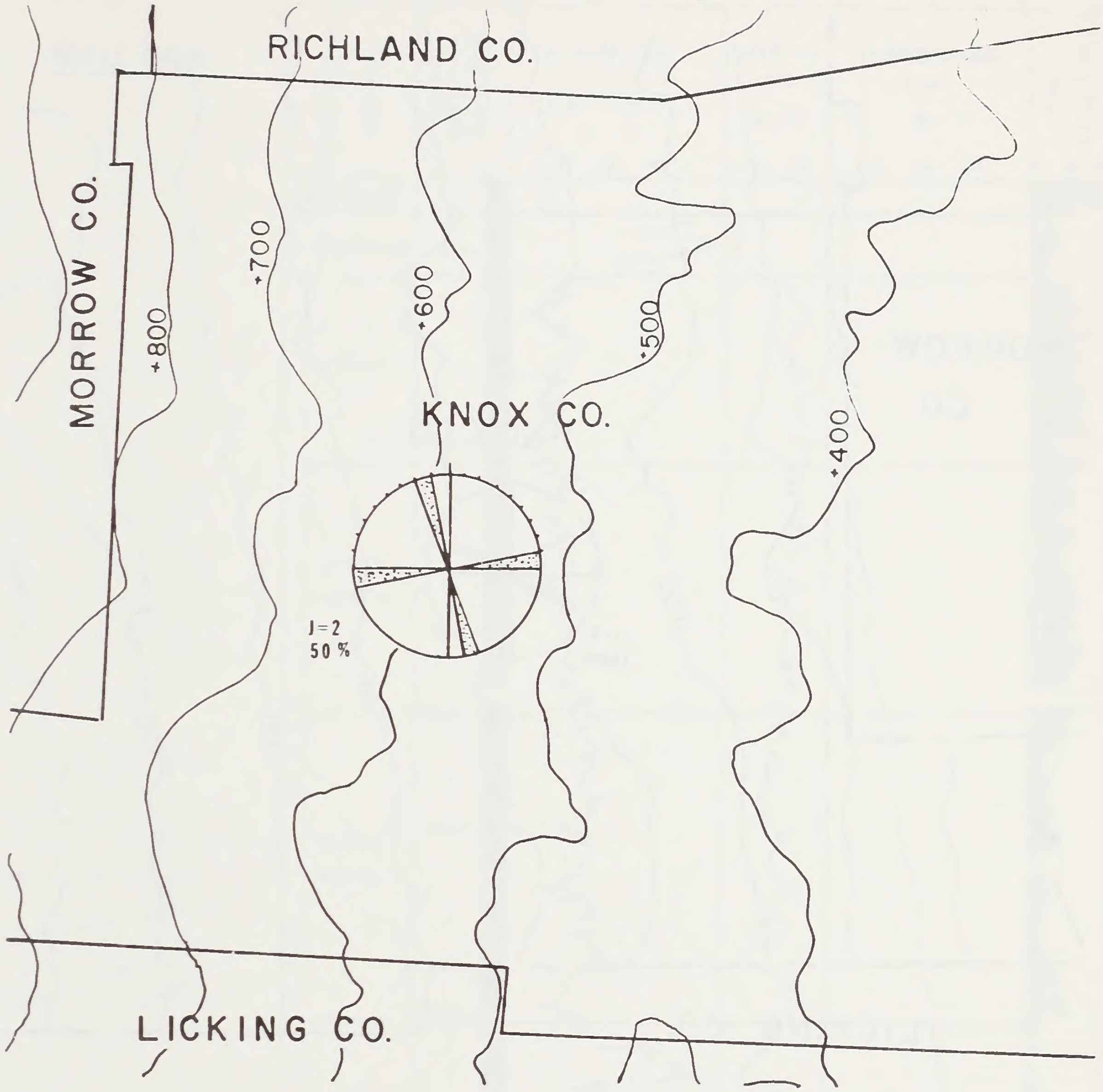
EGSP OHIO-3 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

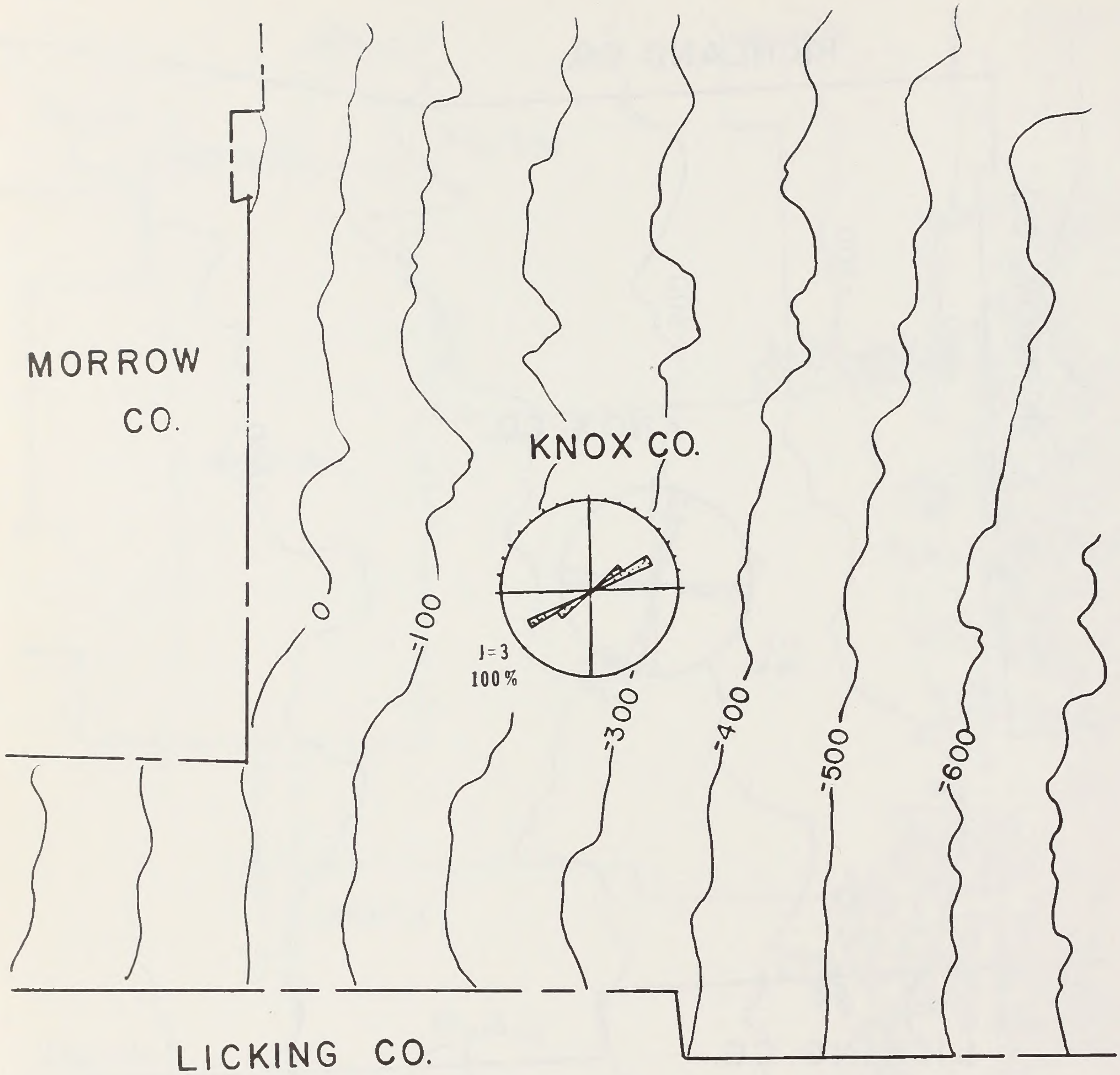
Pp&a	Pottsville & Allegheny	Pennsylvanian
Mw&a	Waverly & Maxville	Mississippian
Dol	Olentangy & Ohio	Devonian

SCALE 1:500,000

FIGURE 3A



EGSP OHIO-3
STRUCTURAL CONTOURS
TOP OF BEREA SANDSTONE
Scale 1:250,000
FIGURE 3B



EGSP OHIO-3
STRUCTURAL CONTOURS
TOP OF ONONDAGA LIMESTONE
Scale 1:250,000
FIGURE 3C

TOTAL NUMBER OF LINEAMENTS PER 10° AZIMUTH

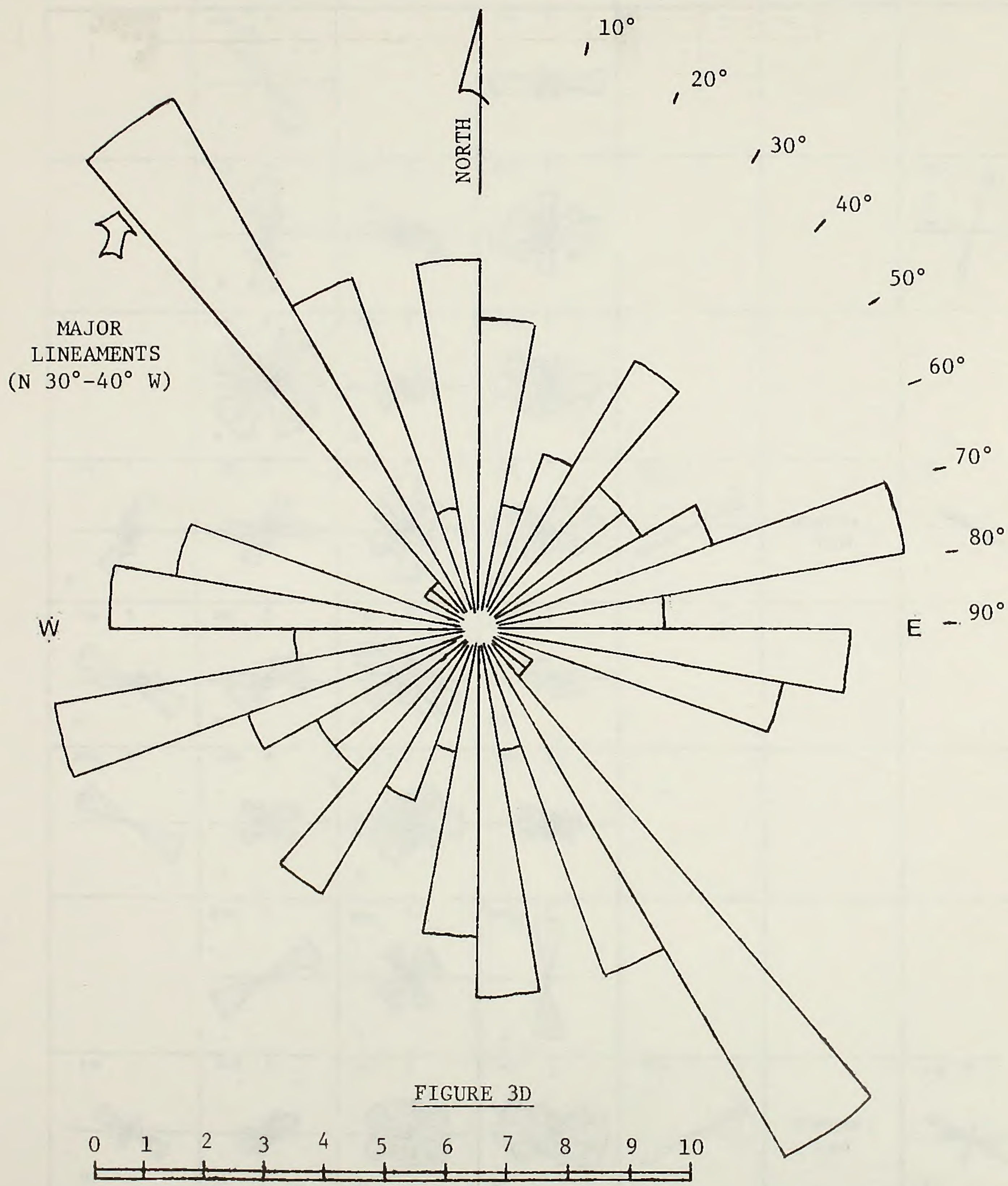


FIGURE 3D

Shafer Exploration Company, Inc.

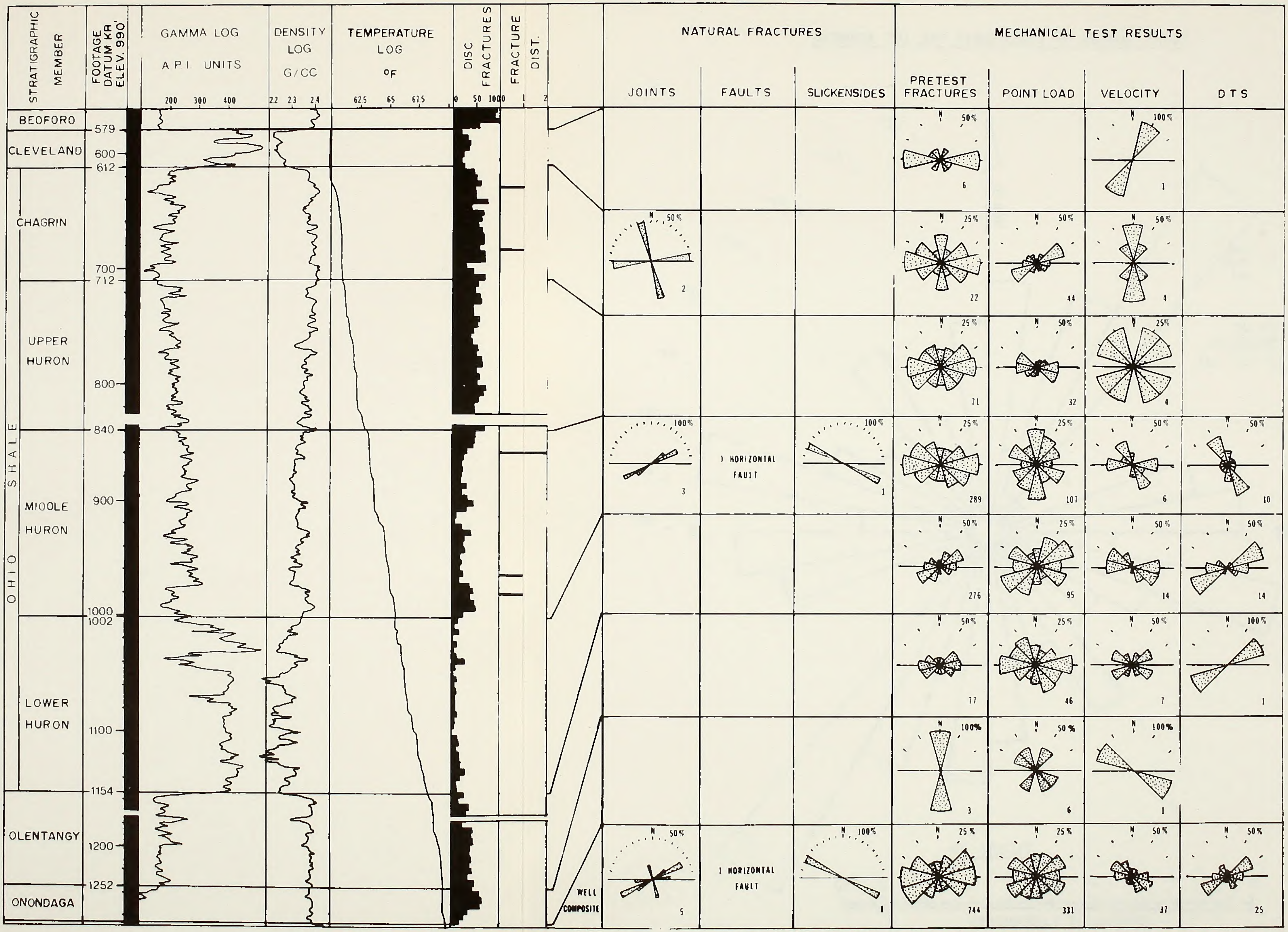


FIGURE 3E E.G.S.P. OHIO 3 WELL SUMMARY.

CLIFFS MINERALS, INC.

EGSP-OHIO #4 (MONSANTO RESEARCH CORP.) WELL

LOCATION

The EGSP-Ohio #4 well was drilled in the NE corner of Ashtabula County, Ohio, south of the city of Conneaut. The exact location is 6500'S of latitude 41°57'30"N by 2900'W of longitude 80°32'30"W (Figures 1, 4A and Table 1).

GEOLOGY

The well is located in glaciated terrain south of Lake Erie. Subsurface bedrock geology is composed of Upper Devonian Chagrin Shale and the stratigraphic nomenclature is that used by the U.S.G.S. in Chart OC-62. The Onondaga structure map indicates a change in strike of the bedding and a possible fault to the southwest of the well site (Figure 4B). Eight intervals were cored from 508' to 1,386', beginning in the Chagrin Shale and terminating in the Onondaga Limestone. See the well summary chart (Figure 4C) for details.

PRODUCTION DATA

No commercial gas production has been obtained from this well. The well was drilled in an area of reported gas shows from the Devonian sediments, immediately west of the Girard Field in Erie County, Pennsylvania. The field has produced gas from the Devonian section (Tetra Tech, 1980). Temperature logs indicate possible gas shows in the Chagrin Shale above the core point.

CORING-INDUCED FRACTURES

A total of eight petal fractures occur in the cored intervals. One is in the Chagrin Shale trending N60°E, six are in the Rhinestreet

Shale with equal trends of N60°E and E-W, and one is in the Marcellus Shale trending N60°W.

The N60°E to E-W orientation correlates with the major stress field for the basin. Disc fractures are surprisingly few compared to Ohio #3 (Beckholt #1) and Ohio #5 (McGuire #20149-T) which are also shallow wells occurring in glaciated terrain.

NATURAL FRACTURES

Joints:

Only one joint, oriented N70°E, was observed in the lower section of the Rhinestreet Shale. Infrequent jointing was also observed in the other shallow EGSP Ohio wells in Lorain and Knox counties.

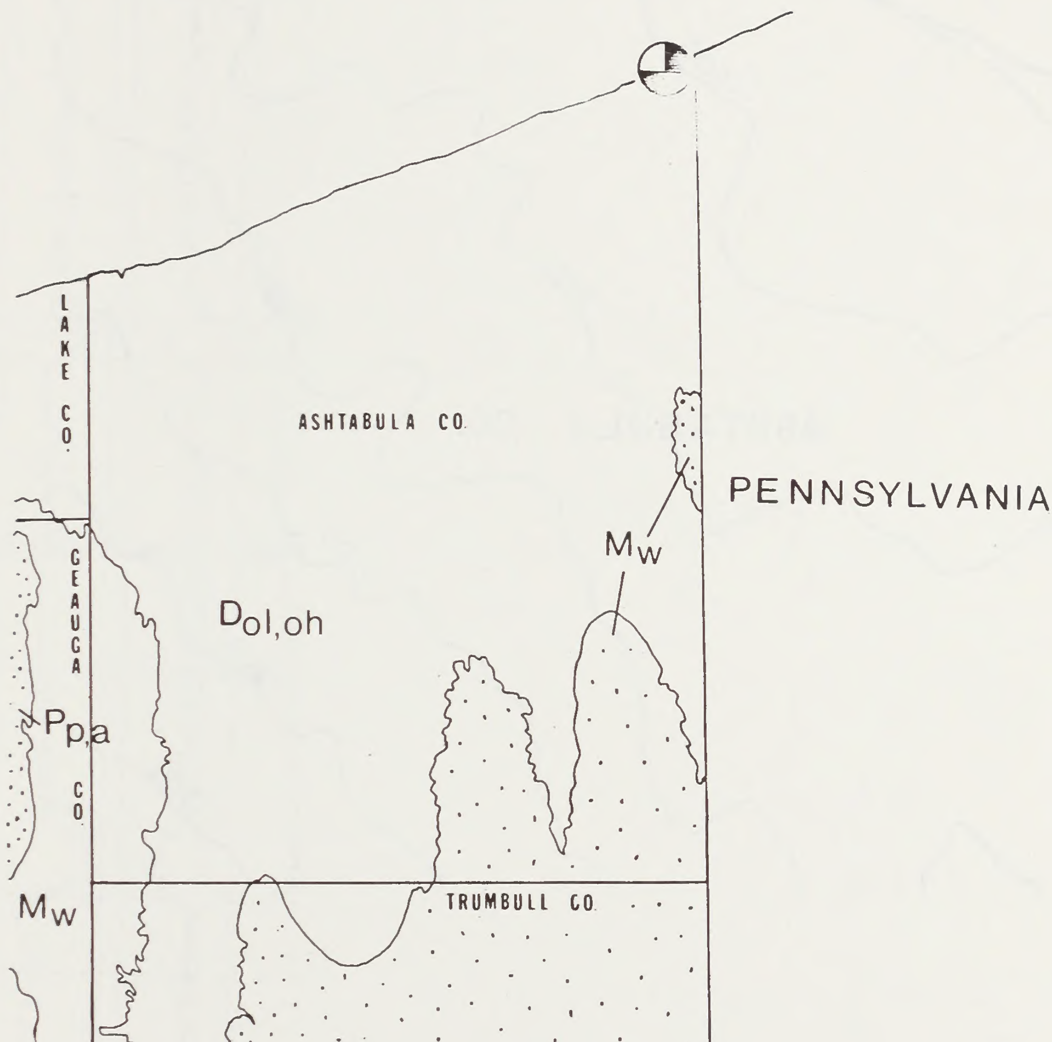
Faults:

No faults were observed in the core.

MECHANICAL TEST DATA

Pretest fractures show a definite NW orientation which is normal to Appalachian folding. This feature is especially noticeable in the Chagrin and Java Members.

Velocity measurements indicate an E-W fabric which parallels the postulated stress field in this area. Point load tests indicate a N60°E orientation of failure for these rocks. The random orientation of tests above 1,000' may have resulted from unloading, whereas the lower section (below 1,000') correlates better with test results.



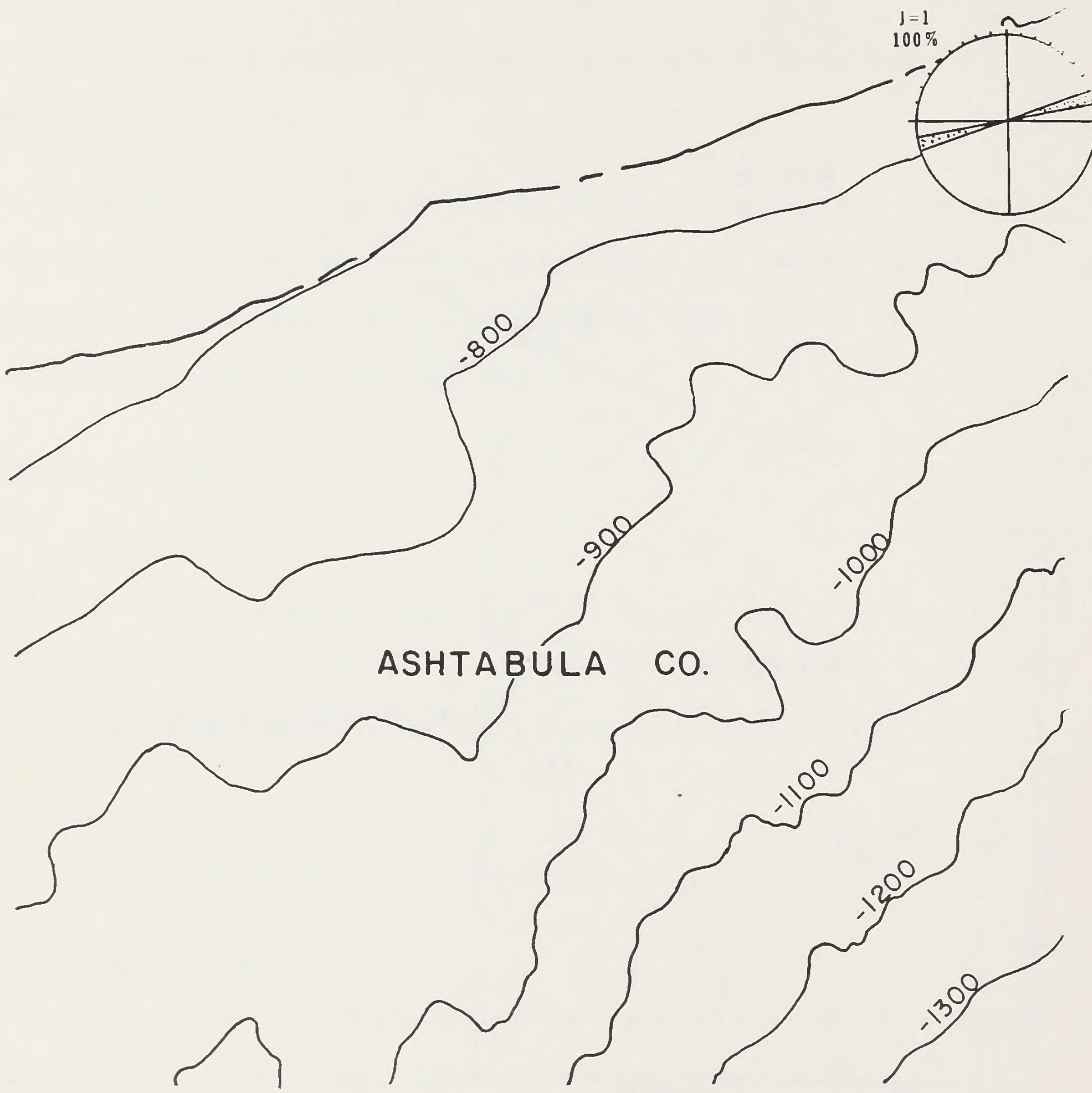
E.G.S.P. OHIO-4 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

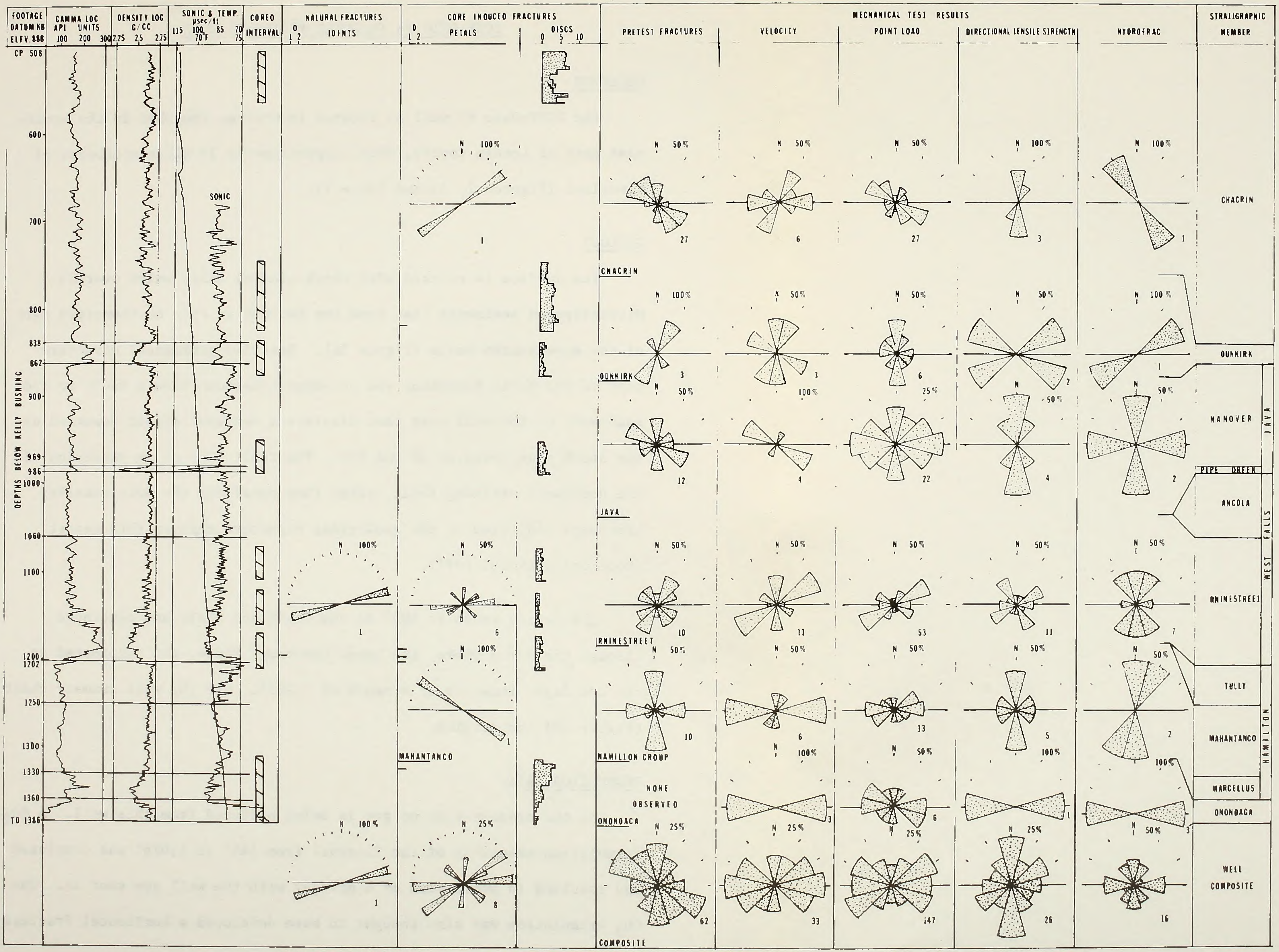
Pp,a	POTTSVILLE & ALLEGHENY	Pennsylvanian
Mw	WAVERLY	Mississippian
Dol,oh	OLENTANGY & OHIO	Devonian

SCALE 1 : 500,000

FIGURE 4A



EGSP OHIO-4
STRUCTURAL CONTOURS
TOP OF ONONDAGA LIMESTONE
Scale 1:250,000
FIGURE 4B



"U": DISTRIBUTION OF FRACTURES

FIGURE 4C E.G.S.P. OHIO 4 WELL SUMMARY

EGSP-OHIO #5 (McGUIRE #20149-T) WELL

LOCATION

The EGSP-Ohio #5 well is located in Grafton Township in the southeast part of Lorain County, Ohio, approximately 30 miles southwest of Cleveland (Figures 1, 5A and Table 1).

GEOLOGY

The surface is covered with thick glacial tills which overlie Mississippian sediments that form the bedrock in this northwestern part of the Appalachian Basin (Figure 5A). Detailed geological structure maps of the Berea Sandstone and Onondaga Limestone show a fault to the southwest of the well site that displays a vertical offset downward on the south side (Figures 5B and 5C). The fault lies on an extension of the northwest striking fault system that parallels the 40th Parallel Lineament indicated on the geological structure maps in this report (Root and Hoskins, 1977).

The coring began at 400' in the Cleveland Shale and continued through the Huron Shale, the Upper Olentangy Shale, and terminated in the Onondaga Limestone at a depth of 1,281'. See the well summary chart (Figure 5D) for details.

PRODUCTION DATA

At the present time no gas is being produced from this well. A CO_2 stimulation treatment of the interval from 541' to 1,076' was completed and resulted in production of 4 mcf/day with the well now shut in. The CO_2 stimulation was also thought to have developed a horizontal fracture

extending from the well which corresponds to the analysis results in the following sections.

CORING-INDUCED FRACTURES

Disc fractures are the only type noted throughout the cored section. The disc fracture frequency on well summary chart (Figure 5D) shows a notable decrease in frequency in the lower part of the Chagrin Member. That change is coincident with apparent gas shows on the noise and temperature logs and offgassing noted in Cliffs Minerals, Inc. Phase I Report on this well.

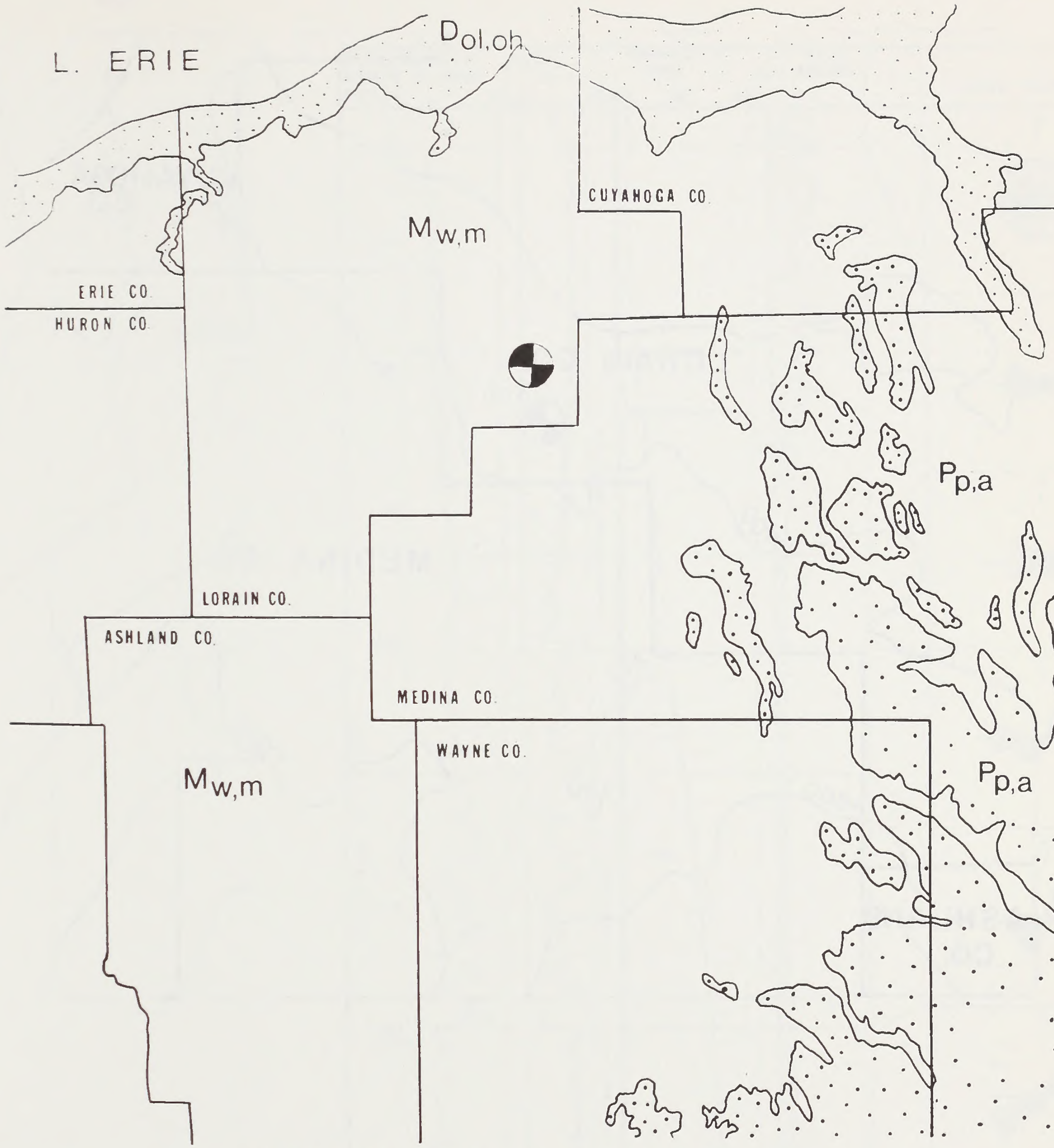
NATURAL FRACTURES

There are no joints or faults in the core retrieved from this well. The only fractures noted are possible bedding plane fractures that have been mineralized with calcite which suggests that at the time of calcite mineralization the minimum stress in this area was the overburden load, resulting from a shallow depth of burial. This situation would also explain why there are no vertical joints in this well.

MECHANICAL TEST RESULTS

A comparison of the mechanical tests shows a wide variation in orientations of the weakness planes defined by each test (Figure 5D). Velocity measurements suggest a N30°E plane of weakness, the point load tests a N30°-60°E trend and the directional tensile strength tests a N30°W trend. The wide variation in trends suggests that the rock has not been sufficiently stressed to create an anisotropy that is as distinct as that displayed by rock nearer to the Allegheny Front.

Lack of vertical joints plus random orientation of the mechanical test results indicate that this area has not been subjected to horizontal stresses sufficient to develop a fracture reservoir system.



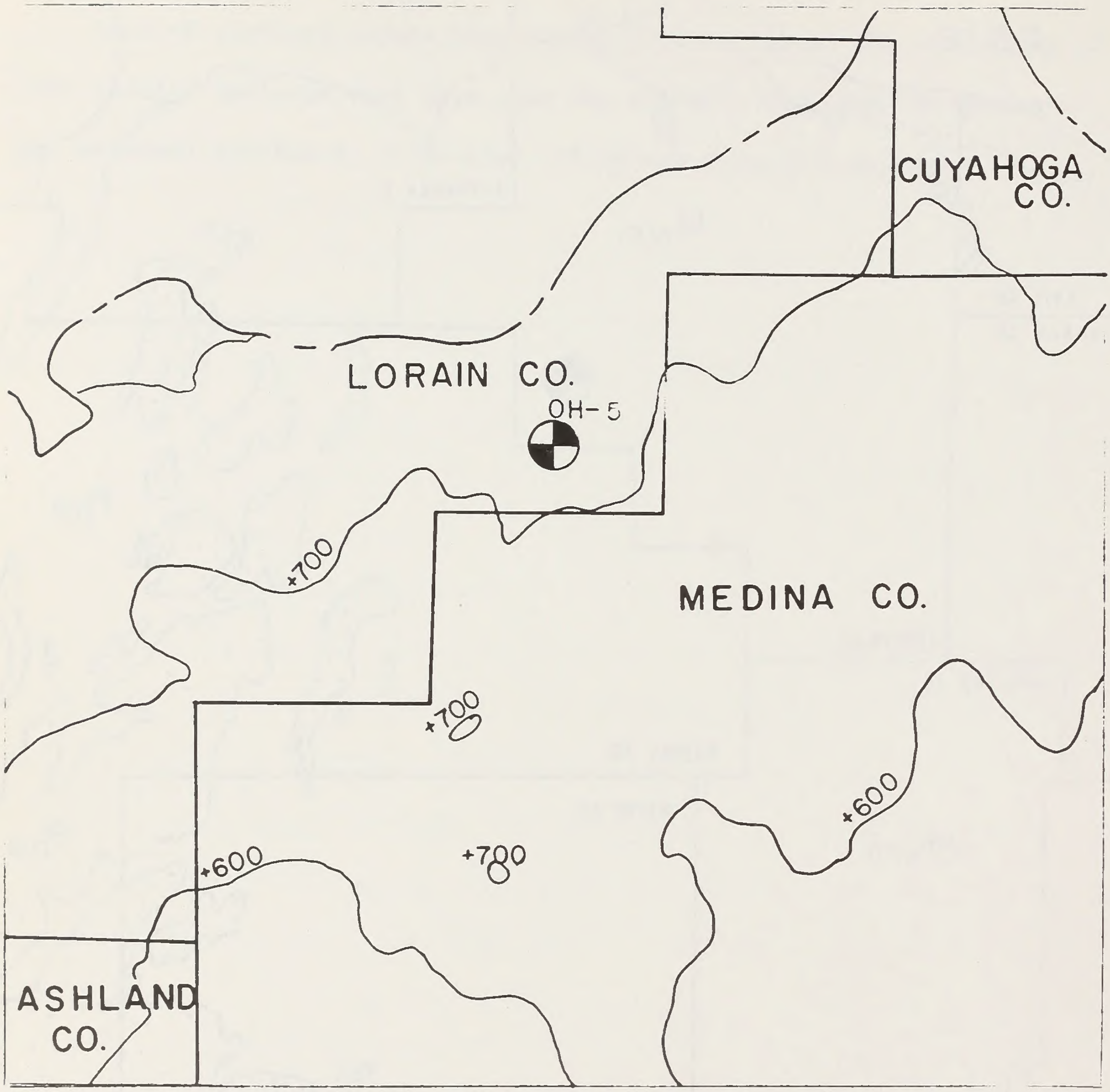
E.G.S.P. OHIO-5 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

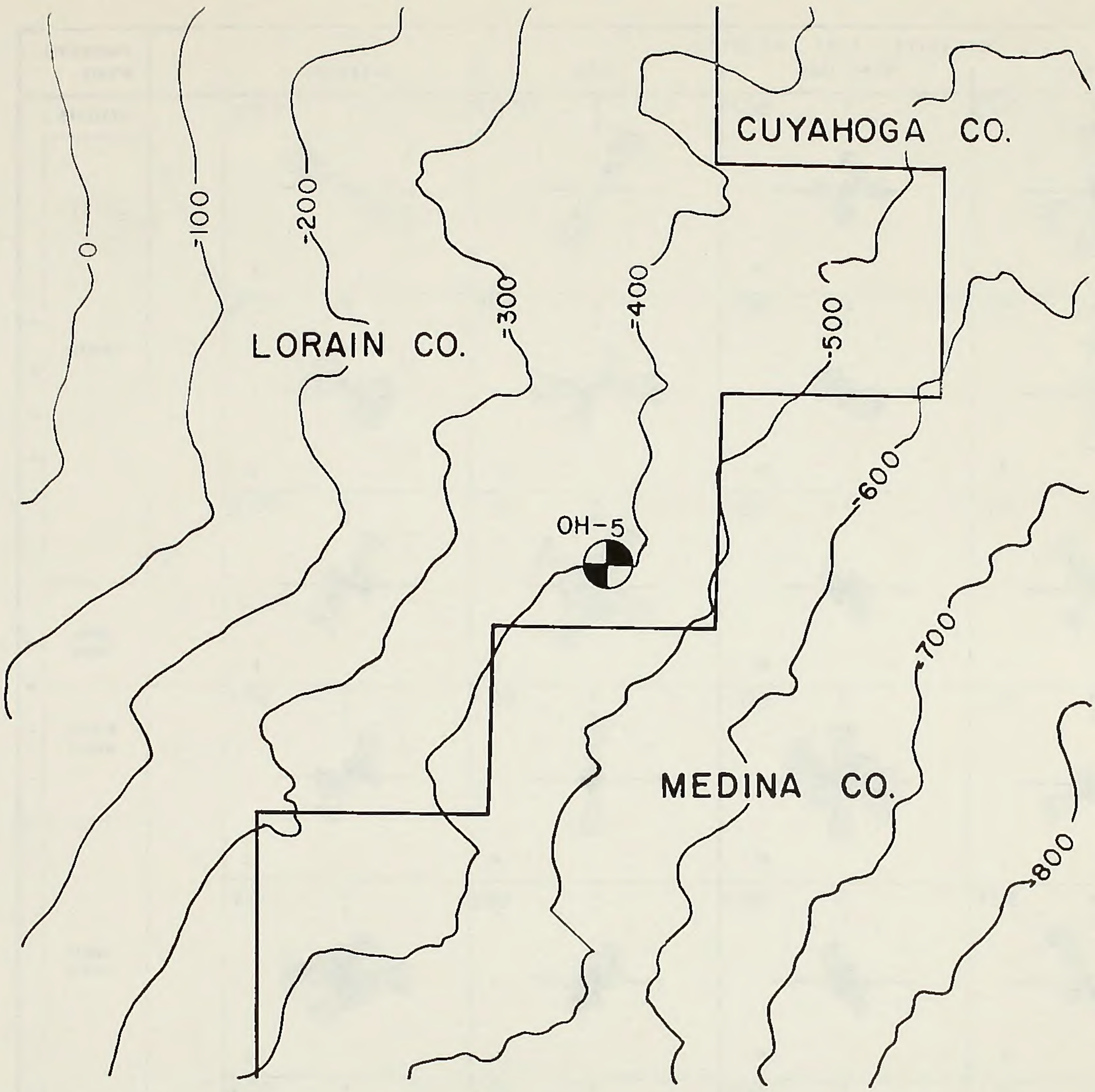
$P_{p,a}$	Pottsville - Allegheny	Pennsylvanian
$M_{w,m}$	Waverly - Maxville	Mississippian
$D_{ol,oh}$	Olentangy - Ohio	Devonian

SCALE 1:500,000

FIGURE 5A



EGSP OHIO-5
STRUCTURAL CONTOURS
TOP OF BEREA SANDSTONE
Scale 1:250,000
FIGURE 5B



EGSP OHIO-5
STRUCTURAL CONTOURS
TOP OF ONONDAGA LIMESTONE
Scale 1:250,000
FIGURE 5C

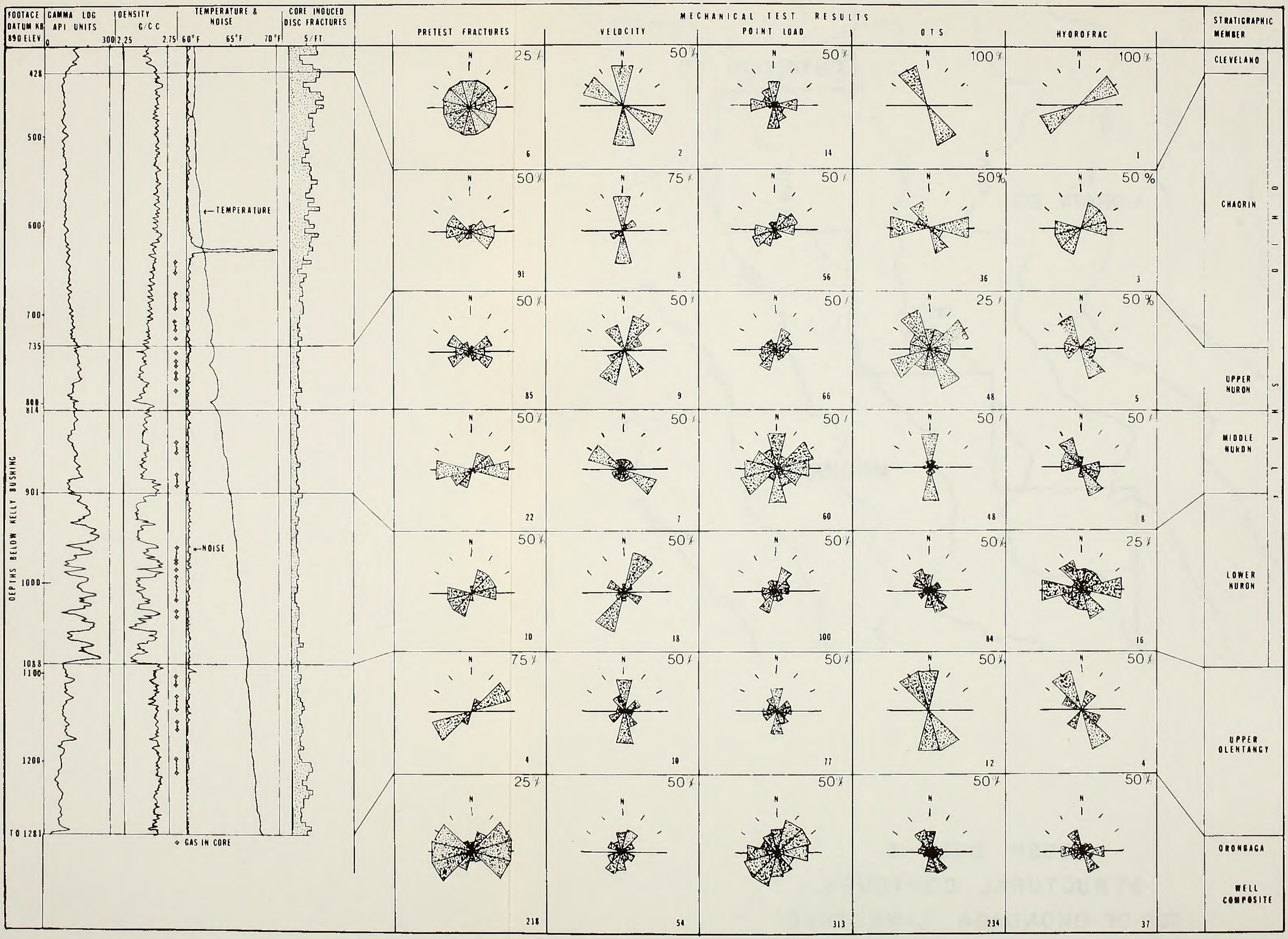


FIGURE 50 E.G.S.P. OHIO 5 WELL SUMMARY

CLIFFS MINERALS, INC.

EGSP OHIO #6 SERIES WELLS

INTRODUCTION

The following five wells were drilled within two miles of each other in Gallia County, Ohio. We have treated each well independently in describing the physical characteristics of the core. A correlation of all well information and its relation to geological structure in the area is included at the end of the detailed well descriptions.

EGSP-OHIO #6-1 (CARPENTER #1-5) WELL

LOCATION

The EGSP-Ohio #6-1 well was drilled in southern Ohio in Walnut Township, Gallia County. The exact position is 320'NL, 1080'WL of Sec. 12 at an elevation of +748' MSL (Figures 1, 6A and Table 1).

GEOLOGY

The well is located on the Precambrian platform east of the Cincinnati Arch and north of the Rome Trough structure of Kentucky and West Virginia. Middle Pennsylvanian Conemaugh sediments constitute the outcrop in the area. The site was determined by the location of an intensely fractured zone overlying a postulated dome-shaped structure on the Onondaga Limestone (Figure 6D). Cored intervals were from 1,810' to 1,866' across the Cleveland-Chagrin Shale contact, 2,310'-2,368' at the Middle to Lower Huron contact and 2,446'-2,501' in the Lower Huron Shale.

PRODUCTION DATA

The well produced no commercial quantities of gas. Only three gas occurrences were noted near the contact between the Cleveland and Chagrin Shales in the "Detailed Lithologic Log" of the Cliffs Minerals, Inc. Phase I Report. This area lies north of Devonian Shale production in Lawrence County, Ohio and west of the Cottageville Field in Jackson and Mason counties, West Virginia.

CORING-INDUCED FRACTURES

Only seven petal fractures were logged in the 169' of core retrieved from the three intervals (Figure 6E). One petal fracture in the Chagrin

has an E-W orientation and the remaining six in the Lower Huron Shale display a N50°E trend. The number of petal fractures is not significant but may indicate a change in stress fields between the Chagrin and Lower Huron Members.

NATURAL FRACTURES

Nine vertical joints were noted in the core (Figure 6E). Two occur in the upper Chagrin Shale with a N40°-50°E orientation and seven in the Lower Huron Shale with a N50°-60°E orientation. Two faults were also measured in the upper Chagrin Shale just below the contact with the Cleveland Shale. One is a high angle fault dipping NE at 42° and the other dips SE at 15°. Both faults strike N60°W. The slickensides on both fault surfaces trend and plunge N30°E, 40°NE and S20°W, 14°SW, respectively. No mineralization was noted in the fractures. Alignment of the slickensides on the two faults and the vertical joint orientations indicate that the same stress field was responsible for forming both types of natural fractures.

MECHANICAL TEST DATA

Pretest fracture measurements indicate a strong E-W orientation for the entire core. In addition, a N30°E trend parallels the slickensides in the Chagrin Shale (Figure 6E).

Ultrasonic velocity tests also display an E-W orientation throughout the core with a N-S complimentary trend in the Chagrin Shale. Point load tests vary from the latter tests in showing a dominant N60°E trend for the entire well. The variability in orientations indicates the rock has not been subjected to large deformational stresses.

EGSP-OHIO #6-2 (WHITE UNIT #1-7) WELL

LOCATION

The EGSP-Ohio #6-2 well is located 1.35 miles SE of EGSP-Ohio #6-1 at an elevation of +936' MSL (Figures 1, 6A and Table 1).

GEOLOGY

The geologic structure and stratigraphy is the same as Ohio #6-1 with the Pennsylvanian Conemaugh being the uppermost unit encountered in the section. Core was taken from three intervals in the well (Figure 6F). The first was 1,697'-1,755' straddling the Bedford Shale-Cleveland Shale contact. The second and third were at 2,282'-2,341' and 2,418'-2,476' in the upper and lower sections of the Lower Huron Shale.

PRODUCTION DATA

No commercial gas has been produced from this well.

CORING-INDUCED FRACTURES

Two petal fractures at the base of the Bedford Shale display a N45°W orientation. Fourteen petal fractures, aligned N50°-60°E, occur in the lower cored section of the Lower Huron Shale Member. The change in orientation from the Bedford to the Lower Huron seems to indicate a different stress system for each section. Disc fracture frequency is less than 5 per foot throughout the section.

NATURAL FRACTURES

A total of eight vertical joints with a dominant trend of N60°-70°E was noted in the Lower Huron Shale. The lowermost compound joint was mineralized with dolomite (Figure 6F).

Faults show varied strikes in the NW quadrant and dip angles of 25° to 70°. Six faults dip SW and two dip NE. Slickensides are dominantly oriented N20°-30°E with plunge angles varying from 24° to 51°.

MECHANICAL TEST DATA

Bedford and Cleveland Shale testing shows that pretest fractures and velocities have a definite E-W orientation. The point load results for the respective members display opposing trends in the NE and NW quadrants. Lower Huron Shale testing displays a different orientation maximum in each test (Figure 6F). The variation of test results indicates that, due to insufficient stress, a fabric has not been imprinted on the rock.

EGSP-OHIO #6-3 (McCOMB #1-6) WELL

LOCATION

The EGSP-Ohio #6-3 well lies south of EGSP-Ohio #6-1 and southeast of EGSP-Ohio #6-2 (Figures 1, 6A and Table 1).

GEOLOGY

The well was located on the south side of a dome-shaped structure projected in the Middle Devonian Limestone. However, this structure was not observed in the geological analysis of the well data from the five EGSP Ohio #6 series wells drilled on the periphery of the dome or from the detailed structure maps of the Ohio Geological Survey, 1980 (Figures 6B and 6D). Only 70' of core was retrieved from two intervals 1,988'-2,046' across the Bedford-Cleveland-Chagrin Shale contacts and 2,590'-2,602' in the Lower Huron Shale (Figure 6G).

PRODUCTION DATA

No commercial gas has been produced from this well. A massive foam fracture test was performed on the 2,578'-2,820' interval in the Lower Huron and Upper Olentangy Shale. Water flooding problems resulted.

CORING-INDUCED FRACTURES

One petal fracture oriented N70°E was observed in the Lower Huron Shale. The frequency of disc fractures is less than 5 per foot as in the other wells (Figure 6G).

NATURAL FRACTURES

Only two vertical joints, striking N70°E and N02°E, occur in the Lower Huron section. No faults or carbonate mineralization were encountered in the cored section.

MECHANICAL TEST DATA

Test results show diverse orientations within the stratigraphic members related to depth (Figure 6G). In the Bedford Shale pretest fractures, velocities and point load tests each shows a different trend. The Cleveland Shale has pretest fractures and point load test results showing an E-W trend which may indicate the major horizontal stress orientation. However, velocity tests show a dominant N-S trend which may be a sedimentary fabric. The Lower Huron displays a N60°W trend in the pretest fractures and point load tests, and a NE orientation for velocity tests. The general consensus is that pretest fractures and point load tests are associated with one deformational episode and the velocities represent a rock fabric or another stage of stress in a given stratigraphic member. By observing the variation from one stratigraphic member to another it appears each has reacted differently to the deforming stress.

EGSP-OHIO #6-4 (STRAIGHT UNIT #1-8) WELL

LOCATION

The EGSP-Ohio #6-4 well is the eastern most well of the series drilled in Gallia County, Ohio (Figures 1, 6A and Table 1).

GEOLOGY

The surface geology remains the same, with Mississippian Age strata dominating the outcrops. This is the only well of the series to have the entire stratigraphic section cored from the Sunbury Shale into the Lower Huron Shale (Figure 6H).

PRODUCTION DATA

No commercial gas has been produced from this well. A foam stimulation treatment was performed on the 2,512'-2,752' interval in the Middle and Lower Huron Shales resulting in development of 8 MCF of gas and water flooding problems. Gas occurrences were observed throughout the core during detailed lithological logging.

CORING-INDUCED FRACTURES

Petal fractures display a large variation from member to member (Figure 6H). The upper portion of the drilled section, from the Bedford Shale to the Middle Huron, has a random orientation. The Lower Huron shows a dominant N40°-50°W trend which is a definite shift when compared to the upper section. Disc fractures are much more frequent when compared to the other holes in the series.

NATURAL FRACTURES

Vertical joints show a very prominent N70°-80°E orientation throughout the Middle and Lower Huron Shales (Figure 6H). One joint in the Cleveland Shale strikes N60°E and one in the Bedford Shale strikes N40°W. The stress that formed these joints appears to have been very uniform throughout the stratigraphic sequence.

Faulting is widely varied in the section as though the faults and the vertical joints were not developed at the same time. The fault set in the Bedford Shale displays one prominent NE strike with dips to the NW and SE at fairly high angles (25°-30°). The associated slickensides plunge NW and SE at the same angles. The less prominent NW striking faults all dip to the NE at high angles and suggest a more complex geological structure than in the other EGSP-Ohio #6 series wells. The fault set in the Lower Huron Member is quite different than the upper set. Two faults strike N0°-10°E and N40°-50°W with dips varying from 14°NW-17°SE and 0°NE-34°SW, respectively.

The overall system has at least one set of faulting with slickenside movement parallel to the vertical joint system. The variation in movement indicates a different stress system in each stratigraphic member.

MECHANICAL TEST DATA

Comparison of the mechanical test results from member to member shows a random orientation. Even in the well composite (Figure 6H) a strong trend is lacking in all the tests. Velocity is the only test which shows some alignment to the other wells, suggesting that fabric is the dominant feature in all the shales.

EGSP-OHIO #6-5 (CARTER #1-9) WELL

LOCATION

The EGSP-Ohio #6-5 well is located just south of EGSP-Ohio #6-2 and west of EGSP-Ohio #6-3 (Figures 1, 6A and Table 1).

GEOLOGY

Like the other wells in the Ohio #6 series, the bedrock outcrop is composed of Mississippian sediments. The well was drilled through the Mississippian to the Bedford Shale where the first of three intervals was cored (Figure 6I). Intervals include 1,660'-1,718' from the Bedford Shale through the Cleveland Shale into the Chagrin Shale, 1,940'-1,998' in the Upper Huron Shale, and 2,440'-2,493' across the Lower Huron Shale contact with the Olentangy Shale. The Onondaga Limestone was encountered at a depth of 2,664' below the KB elevation of +681' MSL.

PRODUCTION DATA

No commercial gas has been produced from this well. One massive foam fracture test was run on the interval from 2,231' to 2,446' in the Lower Huron Shale. Water flooding problems resulted.

CORING-INDUCED FRACTURES

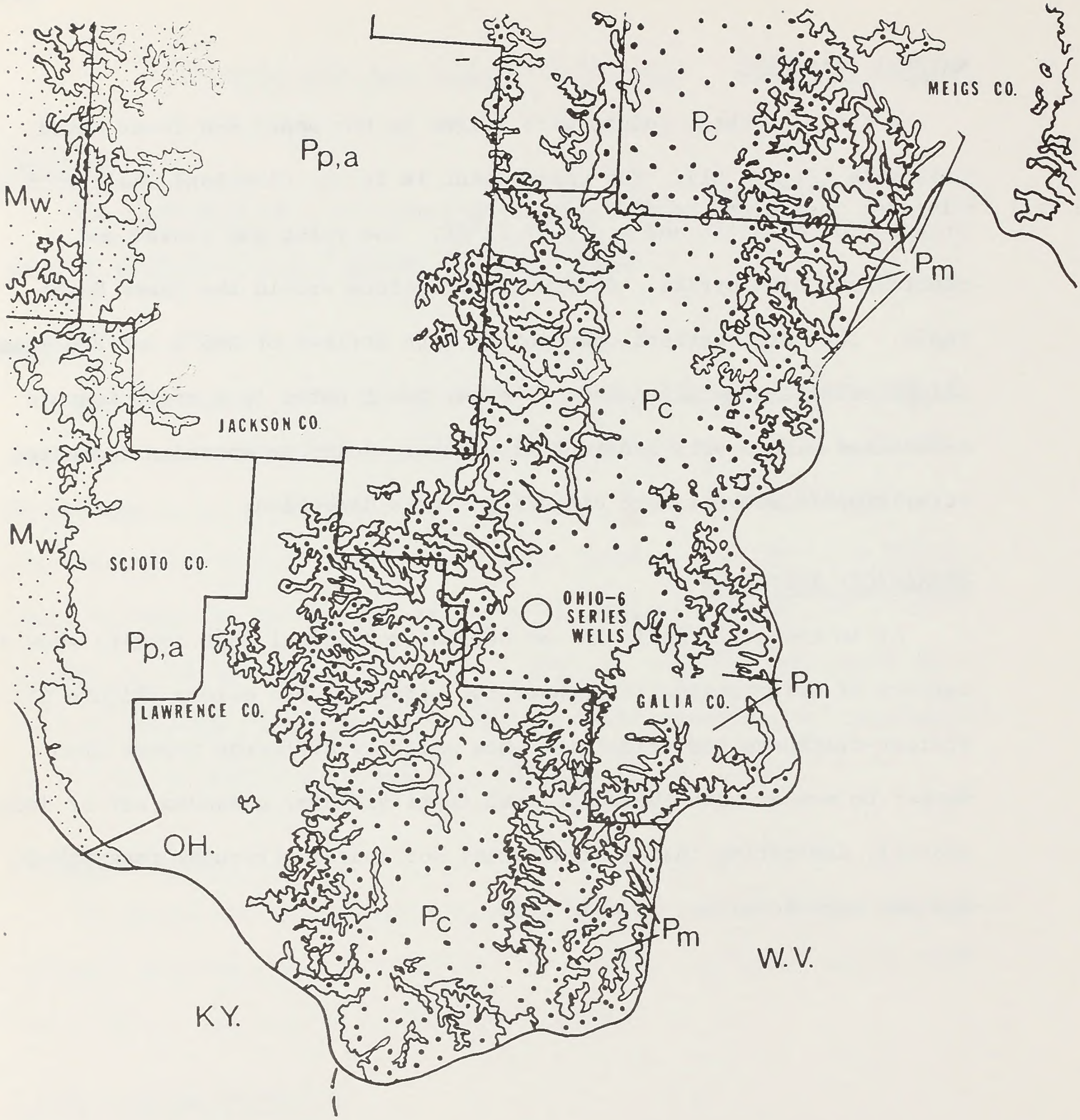
The core displayed only two petal fractures (Figure 6I), one in the Cleveland Shale striking N55°E and one in the Lower Olentangy Shale striking N05°W. The two fractures together with the other well data, indicate a change in rock character in this area. Average disc fracture frequency is less than 5 per foot.

NATURAL FRACTURES

A total of three joints were logged in the upper and lower cored intervals (Figure 6I). The upper joint is in the Cleveland Shale with an orientation of N24°E and a dip of 72°SE. The joint was closed and mineralized with pyrite. The two lower joints are in the Lower Huron Shale. They are vertical open joints with strikes of N65°E and N70°E and slight calcite mineralization. The one fault noted is a small feature associated with a soft sediment structure. Joint orientation indicates stratigraphic members with differing stress direction.

MECHANICAL TEST DATA

As in the other wells in the series, mechanical test results show a variety of orientations throughout the stratigraphic column (Figure 6H). Pretest fractures and velocities show slightly different trends from member to member with the point load tests yielding a random set of data, probably indicating that a significant horizontal stress or rock fabric has not been developed in this area.



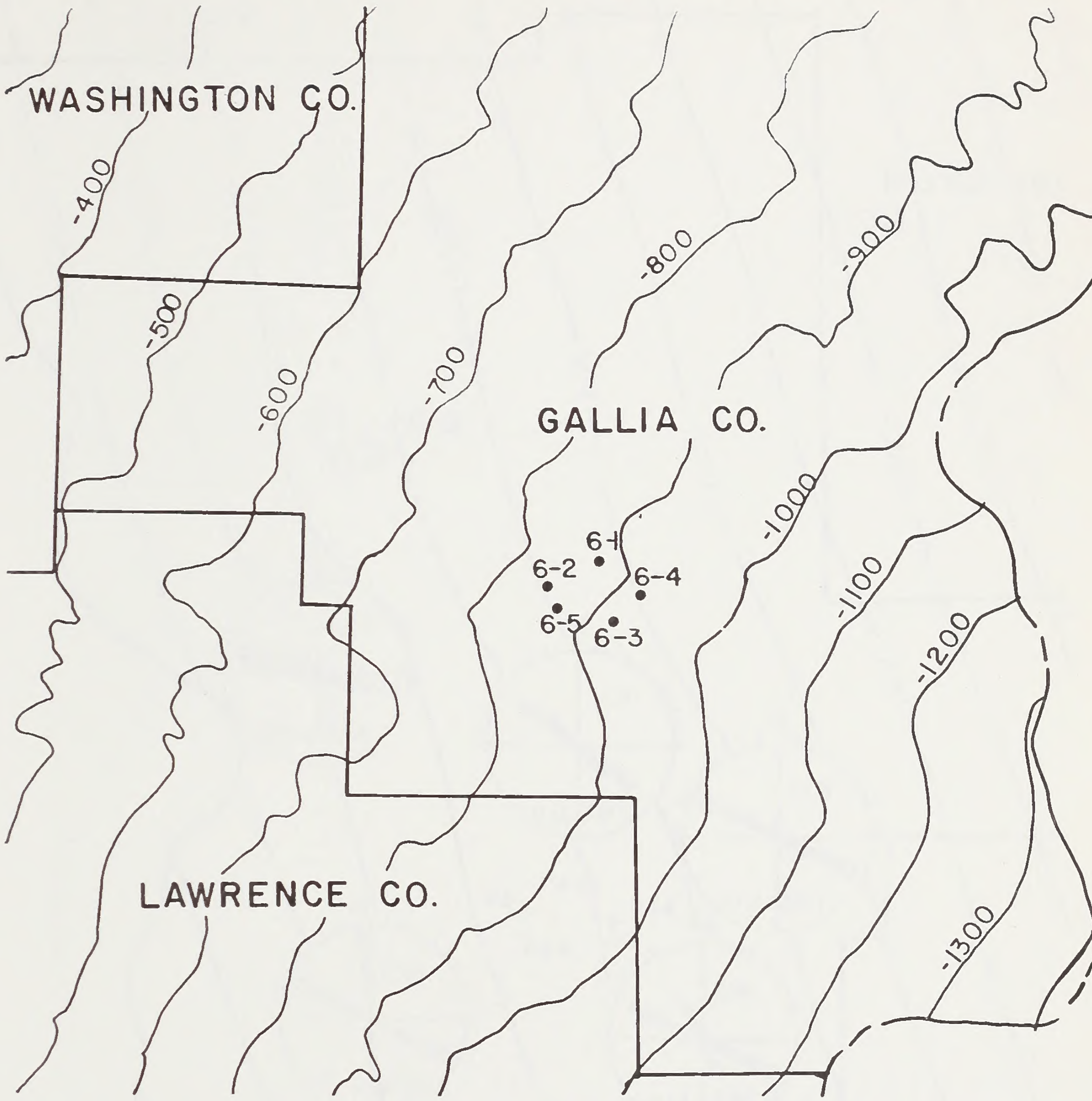
E.G.S.P. OHIO-6 WELLS SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

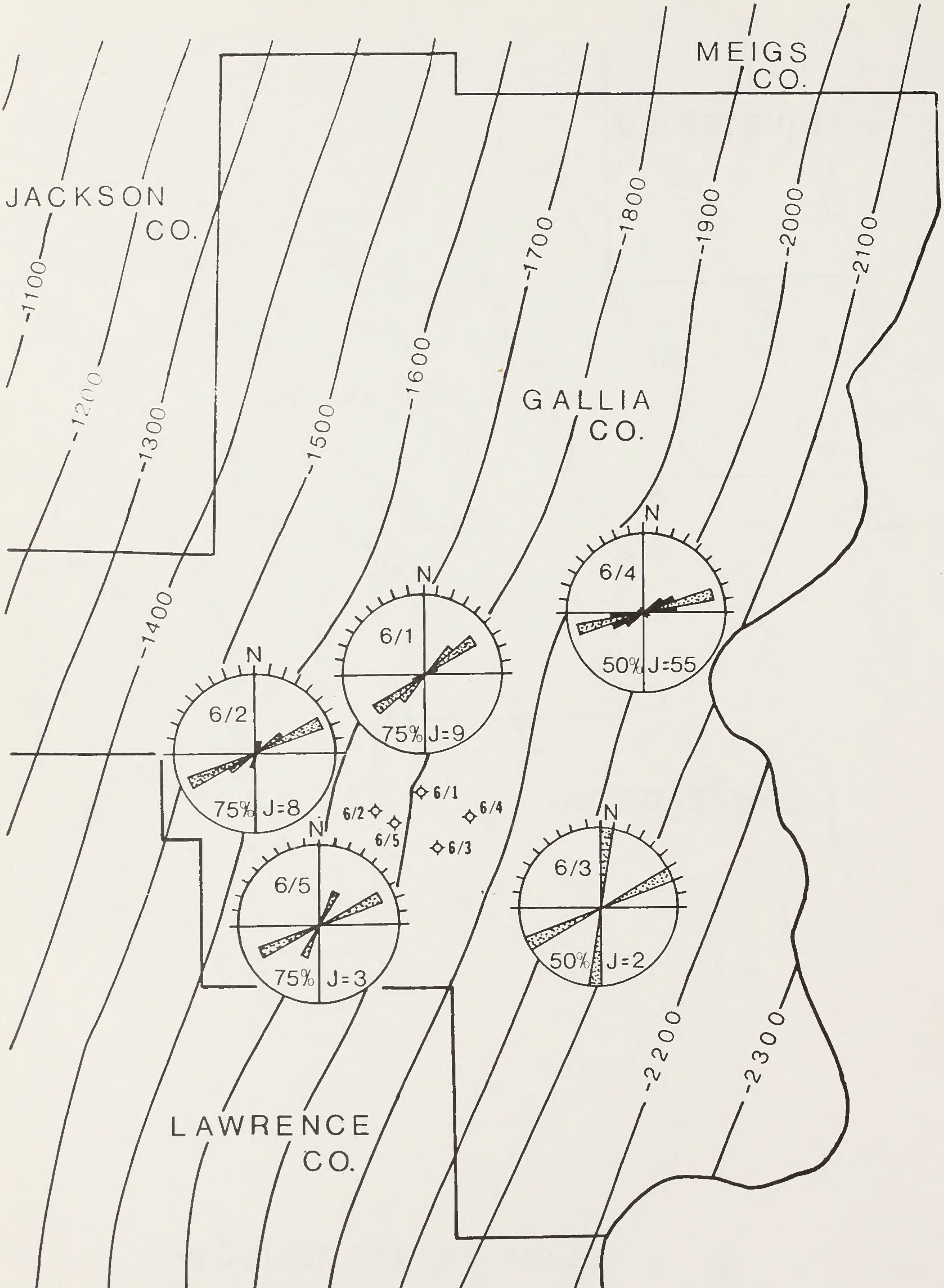
Pm	MONONGAHELA	Pennsylvanian
Pc	CONEMAUGH	
Pp,a	ALLEGHENY & POTTSVILLE	
Mw	WAVERLY	Mississippian

SCALE 1 : 500,000

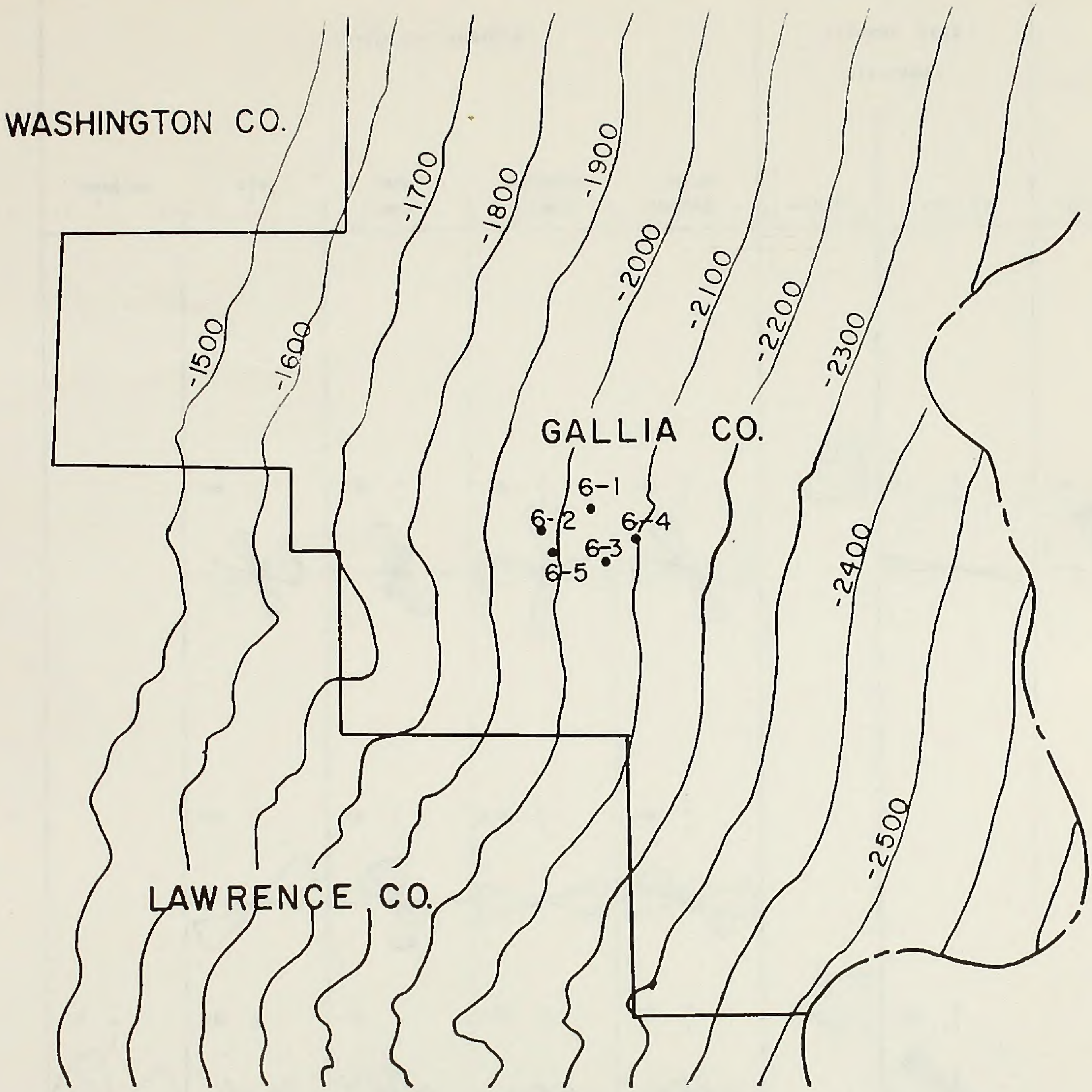
FIGURE 6A



EGSP OHIO-6 SERIES 1-5
STRUCTURAL CONTOURS
TOP OF BEREA SANDSTONE
Scale 1:250,000
FIGURE 6B



EGSP OHIO-6 SERIES
STRUCTURAL CONTOURS BASE OF OHIO SHALE
Scale 1:250,000
FIGURE 6C



EGSP OHIO-6 SERIES 1-5
STRUCTURAL CONTOURS
TOP OF ONONDAGA LIMESTONE
Scale 1:250,000
FIGURE 6D

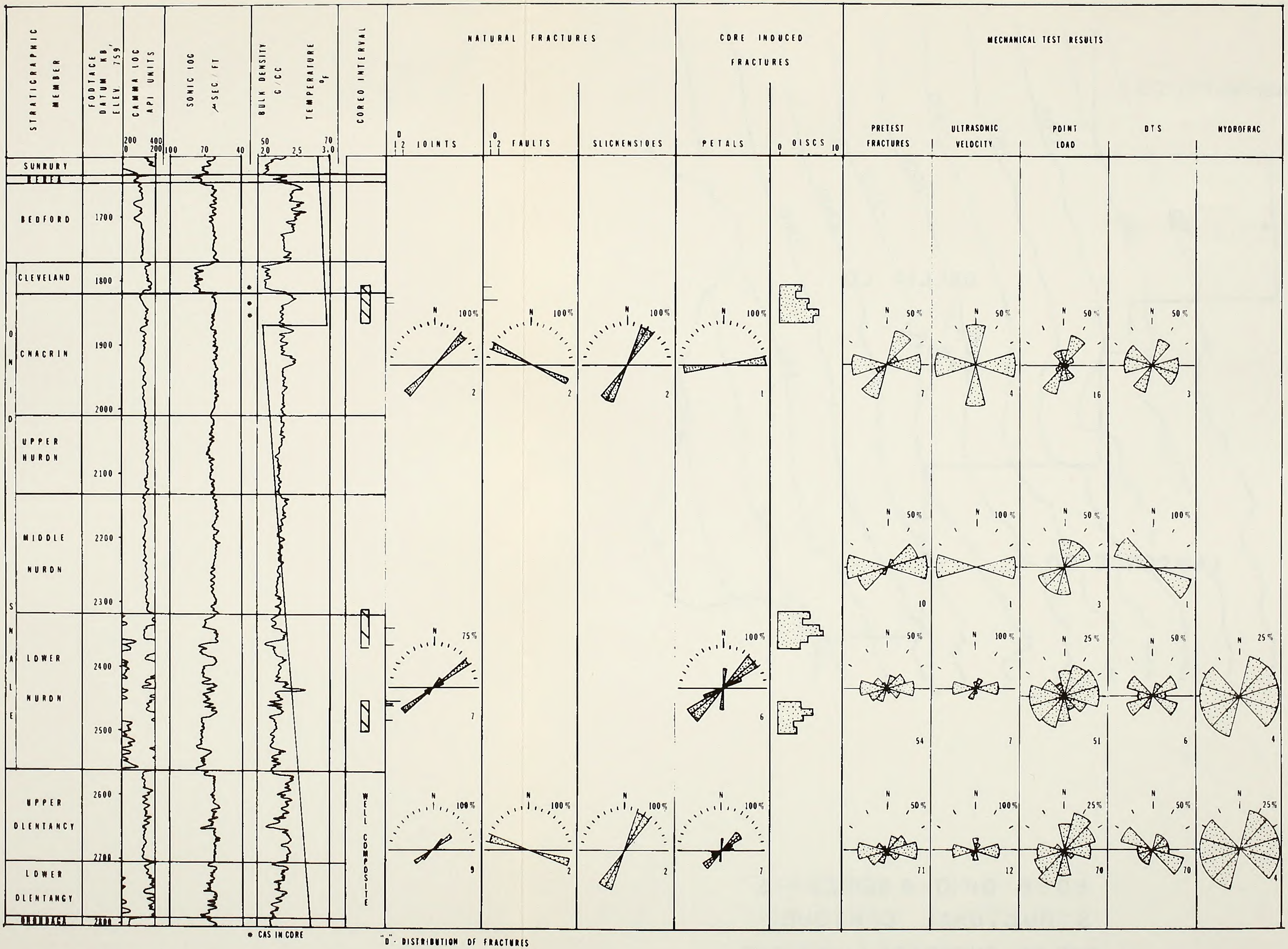


Figure 6E EGSP OHIO 6-1 Well Summary

CLIFFS MINERALS, INC.

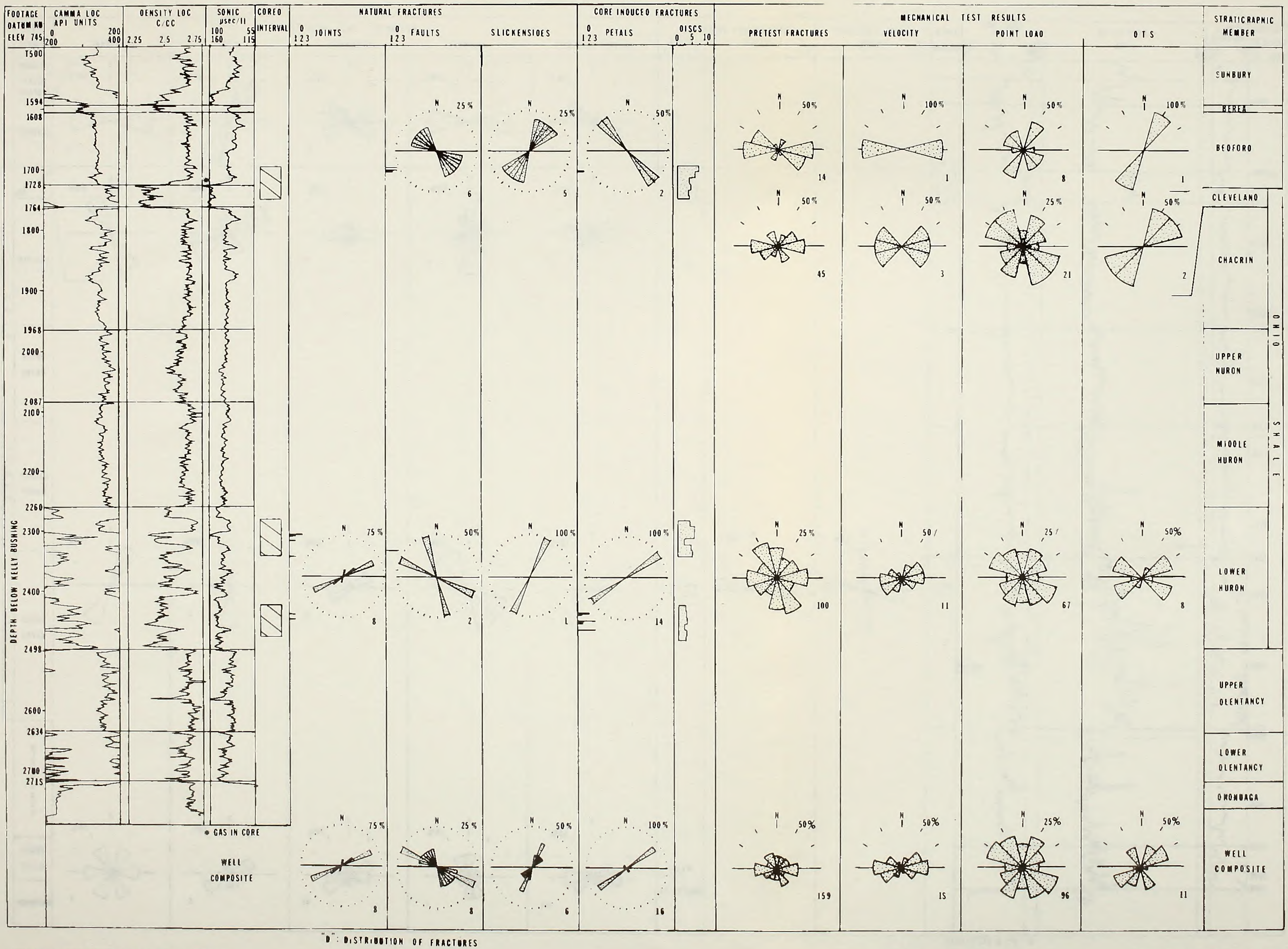


FIGURE 6F E.G.S.P. OHIO 6-2 WELL SUMMARY

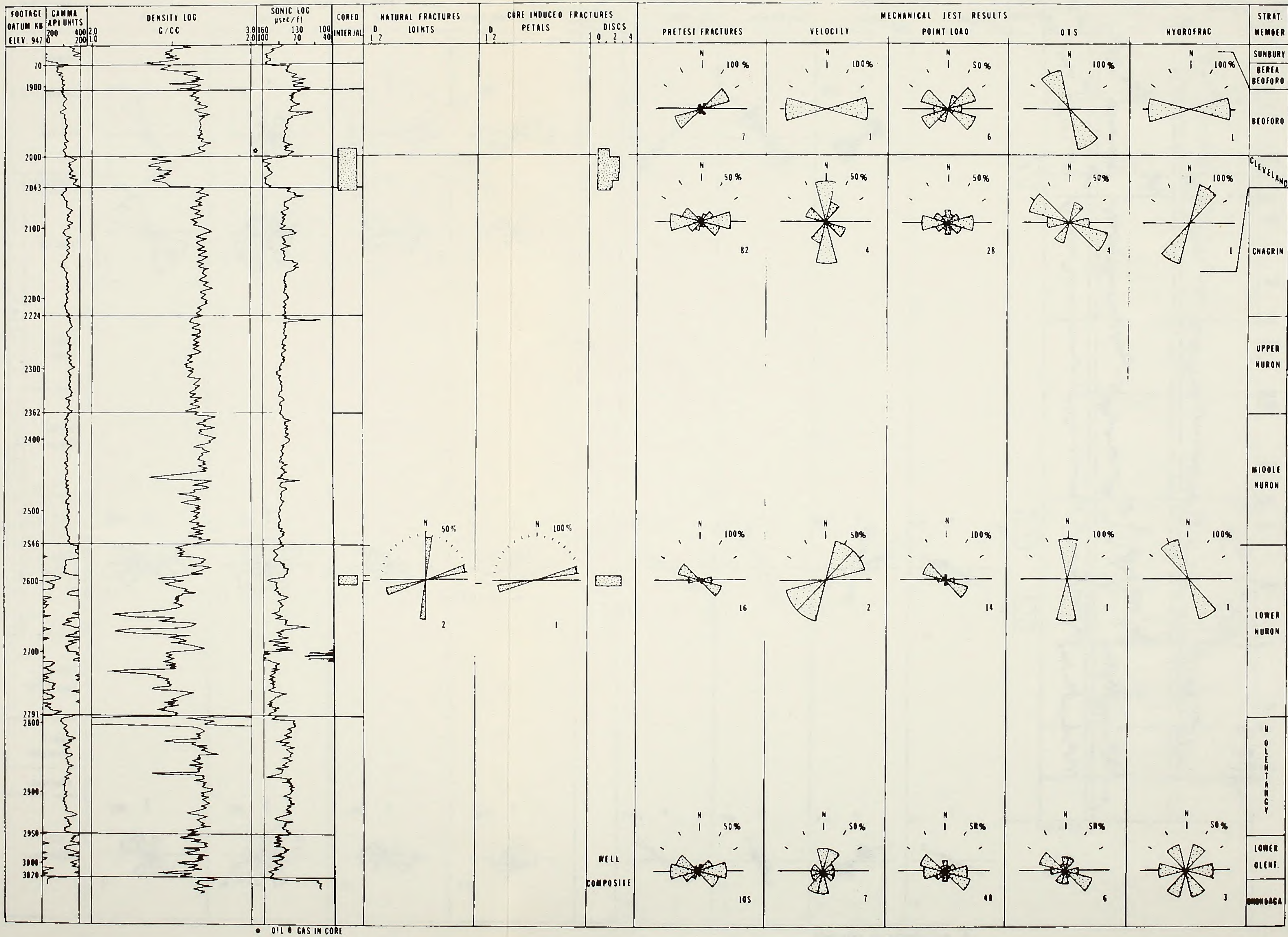


FIGURE 6C E.G.S.P. OHIO 6-3 WELL SUMMARY

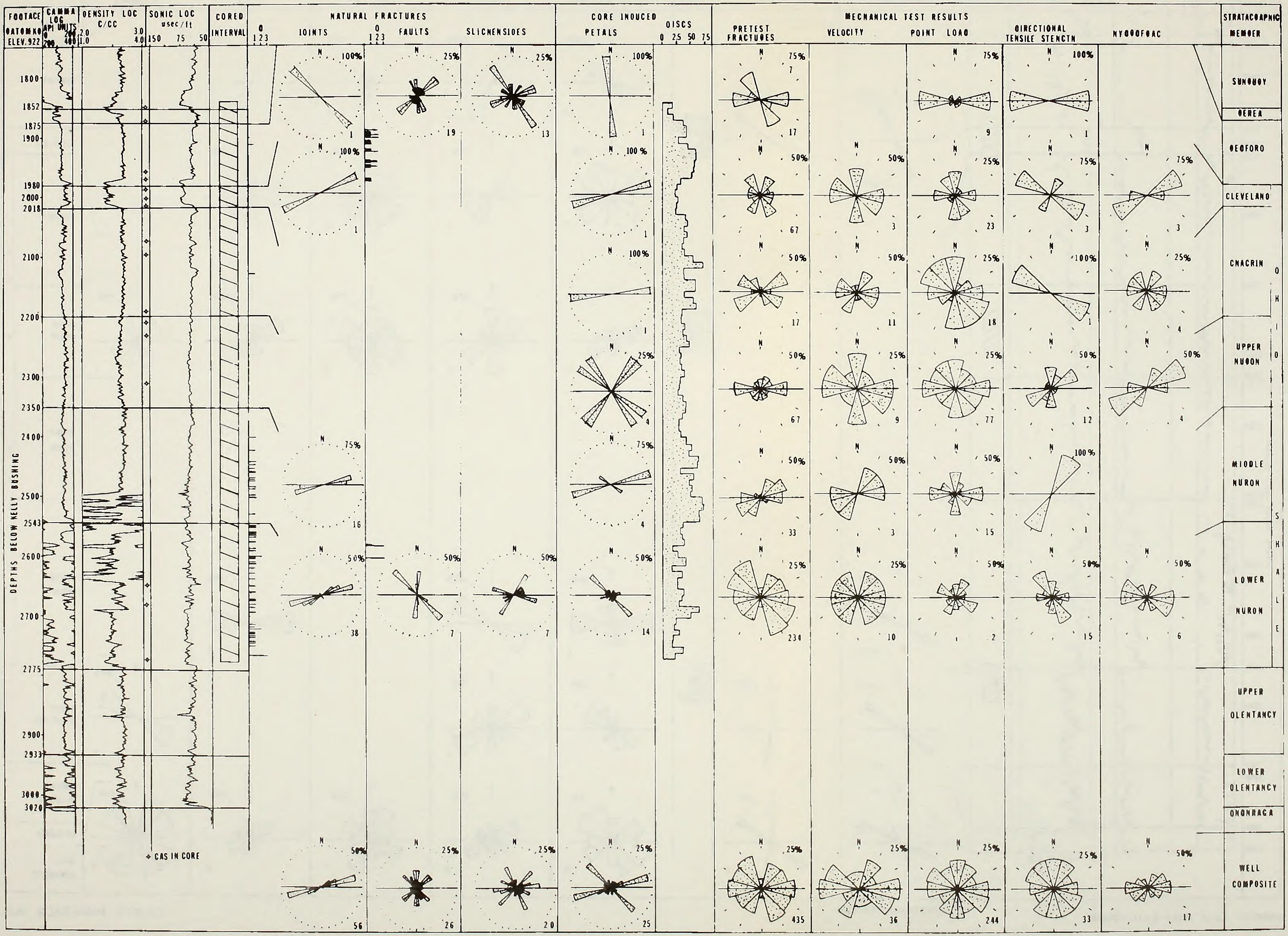


FIGURE 6N E.C.S.P. OHIO 6/4 WELL SUMMARY

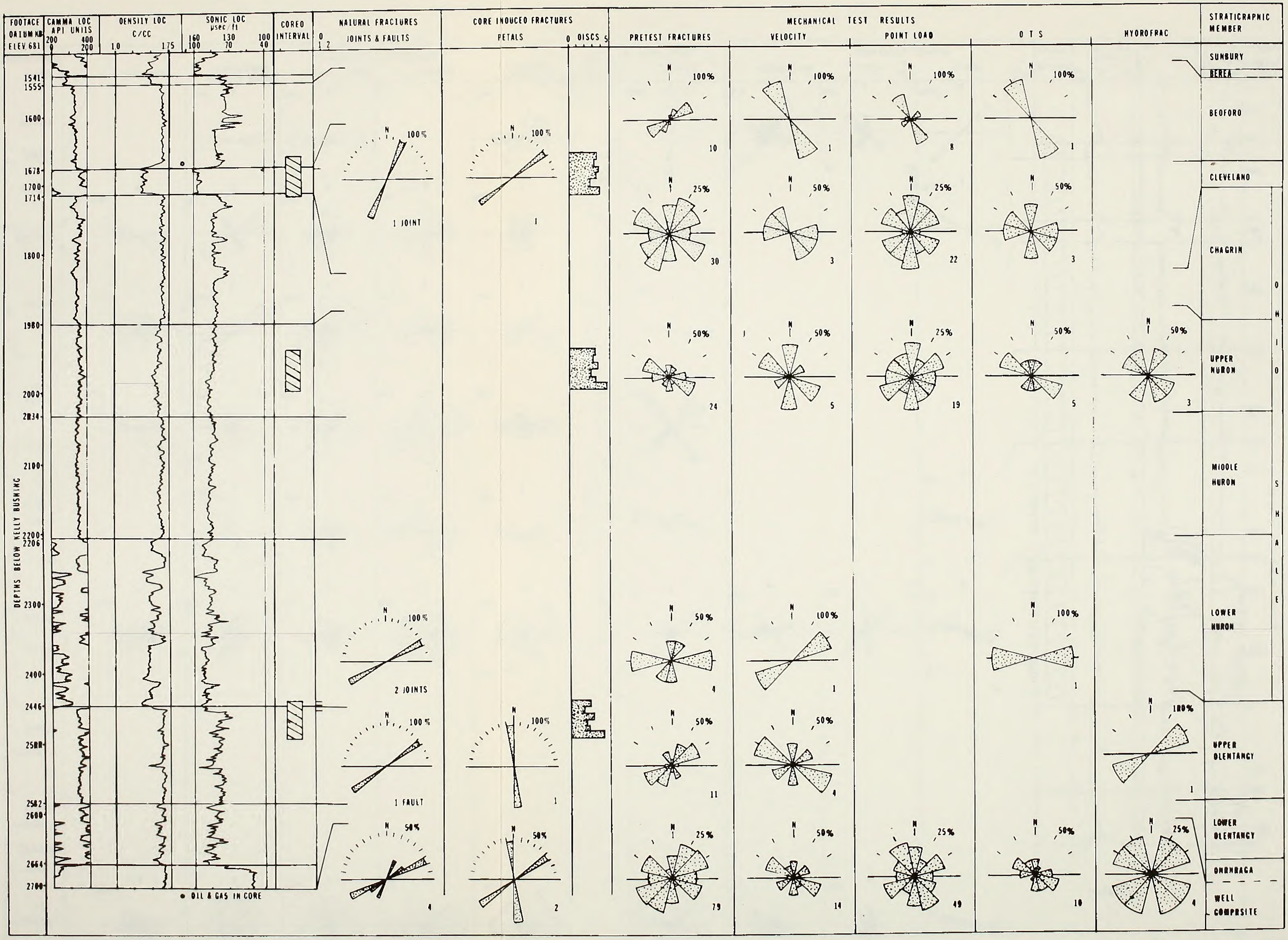


FIGURE 61 E.G.S.P. OHIO 6-5 WELL SUMMARY.

"0": DISTRIBUTION OF FRACTURES

CLIFFS MINERALS, INC.

OHIO #6 SERIES WELLS

SUMMARIES

The Berea Sandstone structure map displays a slight flexure striking N80°W in the area of the well (Figure 6B). The slight change in strike may be due to deposition or deformation in the underlying shales because it is not apparent on the Onondaga map (Figure 6D). A comparison of the natural fracture data in all the wells shows some interesting trends. The joints in all wells strike between N50°-80°E and apparently formed under the same stress conditions (Figure 6C). The faults in the wells are concentrated in the Bedford Shale and the upper part of the Lower Huron Shale Member of the Ohio Shale. The Bedford Shale in Ohio #6-4 (Figure 6H) contains 19 faults with a major slickenside trend N30°-40°W and a minor trend N60°-80°E which parallels the joint strike. The faults in the Lower Huron in Ohio #6-4 show a more varied slickenline trend in the NE Quadrant. In Ohio #6-2 (Figure 6F) the six faults in the Bedford Shale and two faults in the Lower Huron Shale have slickenside trends in the NE quadrant. Overall, a distinct direction of movement on the fault planes cannot be defined in this area.

A comparison of the mechanical test results shows a random trend in all the wells. The only conclusion that can be drawn is that the rock in this area has not been subjected to the amount of deformation that would have developed a rock fabric or anisotropy comparable to the one that deformed the rocks nearer the Allegheny Front.

It is clear that the joints formed under a significant stress field but that it may have been tensile stress normal to joint strikes and not

compressive stress parallel to the joints. Such a stress field may have resulted from relaxation into the Rome Trough structure to the south. The lack of a rock anisotropy or planes of weakness also indicates that this area has not been subjected to compressive stresses of the magnitude applied to rocks nearer to the Allegheny Front.

EGSP-OHIO #7 (COLUMBIA GAS #20143-T) WELL

LOCATION

The EGSP-Ohio #7 well is located in Newton Township, Trumbull County, Ohio. It is approximately two miles SW of the village of Duck Creek in the SE 1/4 of Lot 16 at an elevation of +951'MSL (Figures 1, 7A and Table 1).

GEOLOGY

The geology map of Ohio indicates glacial till at the well site underlain by Lower Pennsylvanian Allegheny and Pottsville sediments (Figure 7A). Geological structure maps on top of the Berea Sandstone and Onondaga Limestone show a change in bedding strike from N75°E to N45°E, respectively (Figures 7B and 7C). The irregularity of the Onondaga contours indicates a complex surface which may include faulting parallel to the vertical faults in the core. The change of strike on the bedding is reflected in the bedrock geology (Figure 7A) and is probably the result of a combination of faulting and sedimentation in this area. Coring began at 1,500' in the Chagrin Shale and ended at 2,710' in the Onondaga Limestone. The members cored include the Huron, Java, West Falls, and Hamilton Group.

PRODUCTION DATA

No commercial gas has been produced from this well. Two massive foam fracture tests were completed on the intervals from 2,488' to 2,589' in the Rhinestreet Member of the West Falls Formation and from 1,865' to 2,147' in the Ohio Shale without success. Considerable off-gassing was observed in the core during the lithologic logging procedure.

CORING-INDUCED FRACTURES

Petal fractures maintain a consistent N40°-60°E orientation where they occur in the Chagrin and Huron Shales. None were noted below the Huron Shale contact with the Java Formation. Disc fracture frequency fluctuates with higher frequencies occurring in the Chagrin, in the lower part of the Huron, and in the Marcellus and Mahantango Shales.

NATURAL FRACTURES

Joints:

Only two small closed joints were recorded in the intertongued Chagrin-Huron Shale section. One is a closed vertical joint striking N44°W and the other is a closed joint striking N78°W and dipping 60°SW. Both fractures have gypsum and anhydrite mineralization which may indicate a geological connection with the Silurian evaporites deeper in the stratigraphic section (Figure 7D).

Faults and Slickensides:

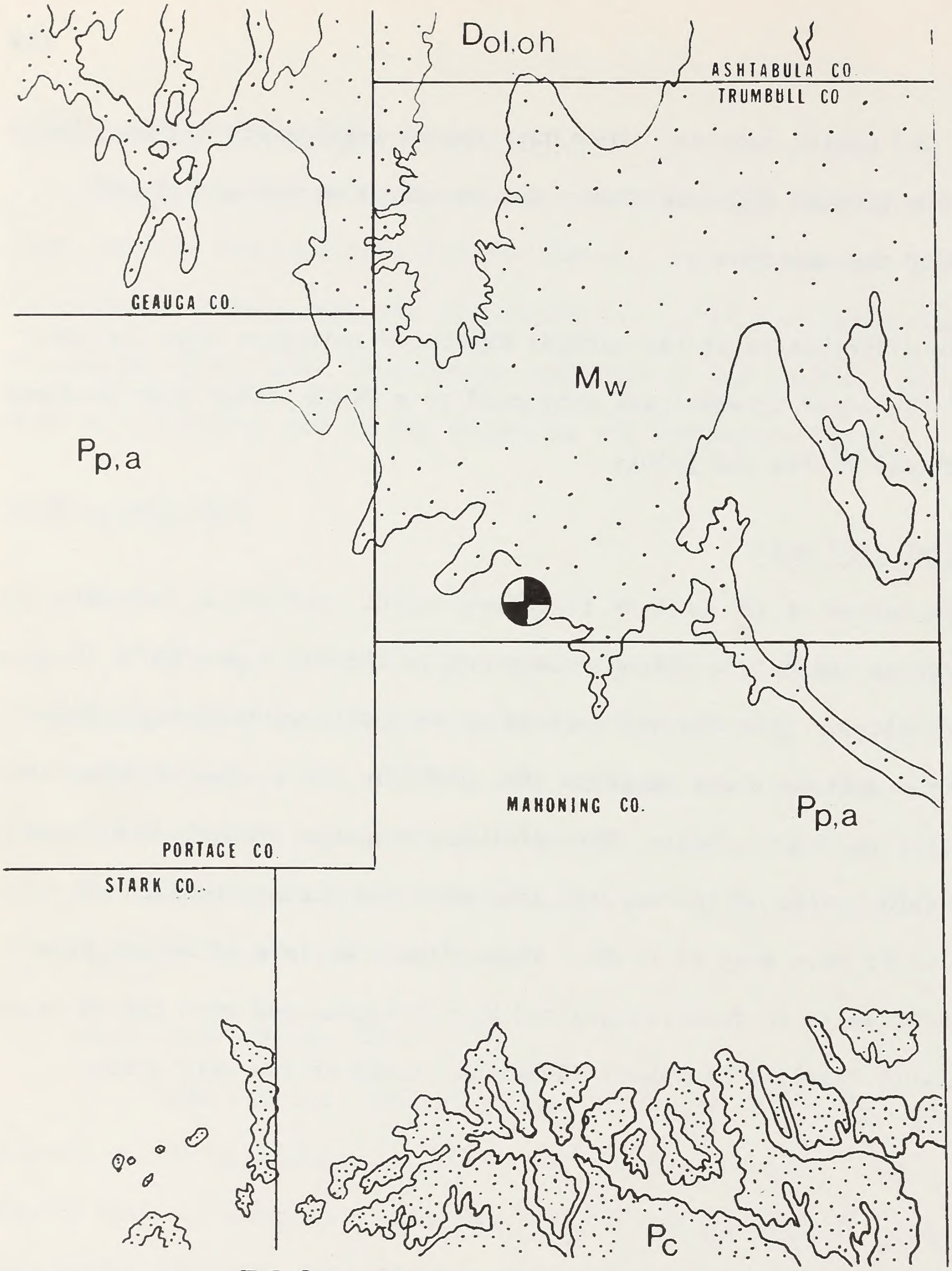
Three vertical faults containing gypsum and anhydrite mineralization occur immediately above the two joints. Likewise, three vertical faults with the same mineralization occur below the joints. The faults all strike N38°-47°W with slickensides developed in the mineralization. Proceeding downhole, the next large fault occurs at 1,849' and strikes N15°E and dips 25°NW. Slickensides occur in two trend directions: N72°W and N25°E. The last fault occurs in the Rhinestreet Member with a N63°W strike and a vertical dip. The fault is mineralized with calcite and displays horizontal slickensides. Many small faults were noted with small structures such as pyritized worm burrows, concretions, sand

lenses, and pyrite nodules. They have random strikes and are very localized, but they do indicate that a deformational stress was present throughout the section.

The distribution of the natural fractures indicates that the upper part of the cored interval was subjected to a NW-SE stress that produced the vertical faults and joints.

MECHANICAL TEST DATA

Composites of the pretest fractures, point load tests, and velocity measurements indicate a strong anisotropy in the N30°E and N60°E (Figure 7D) directions. This feature correlates very well with coring induced fracture orientation and suggests that N60°E is the preferred direction of fracturing for the well. Natural fractures were probably developed during deformation of the Appalachians when the maximum horizontal stress would have been SE to NW. These data correlate with that from other EGSP wells in Pennsylvania and West Virginia and with the NW trend of the 40th Parallel Lineament identified south of the well site.



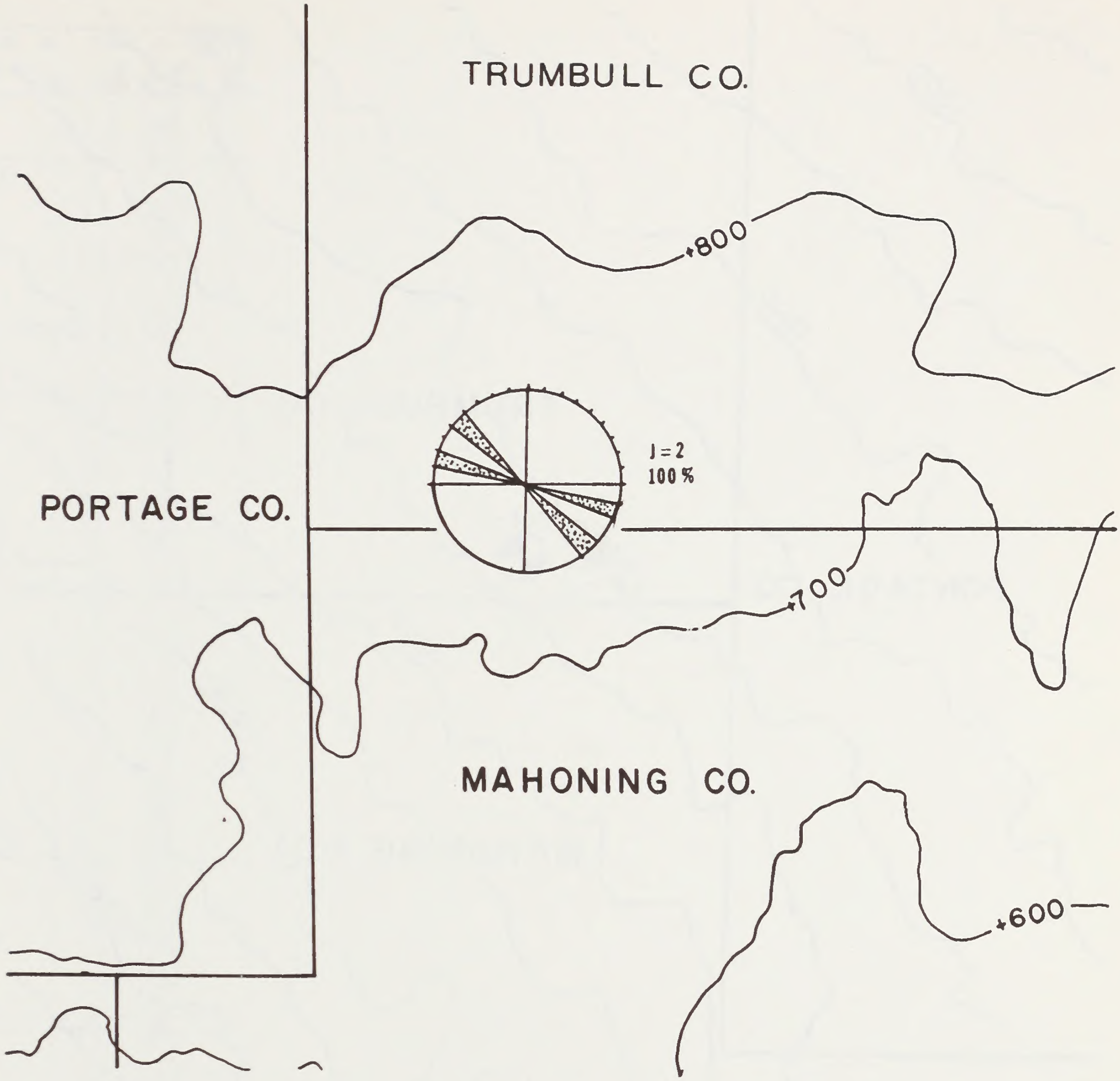
E.G.S.P. OHIO-7 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

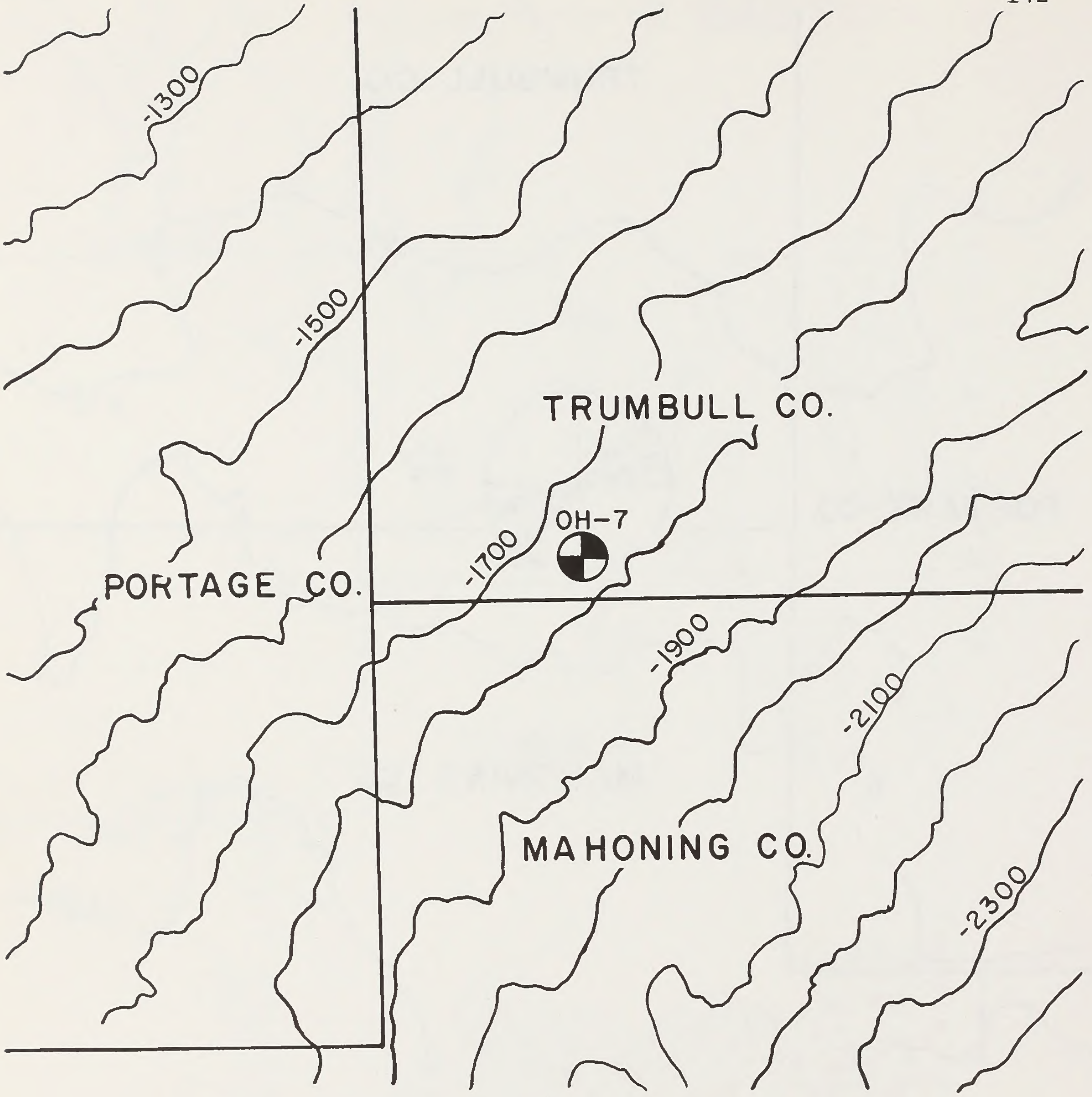
Pc	CONEMAUGH	Pennsylvanian
Pp,a	POTTSVILLE & ALLEGHENY	
Mw	WAVERLY	Mississippian
Dol,oh	OLENTANGY & OHIO	Devonian

SCALE 1:500,000

FIGURE 7A



EGSP OHIO-7
STRUCTURAL CONTOURS
TOP OF BEREA SANDSTONE
Scale 1:250,000
FIGURE 7B



EGSP OHIO-7
STRUCTURAL CONTOURS
TOP OF ONONDAGA LIMESTONE
Scale 1:250,000
FIGURE 7C

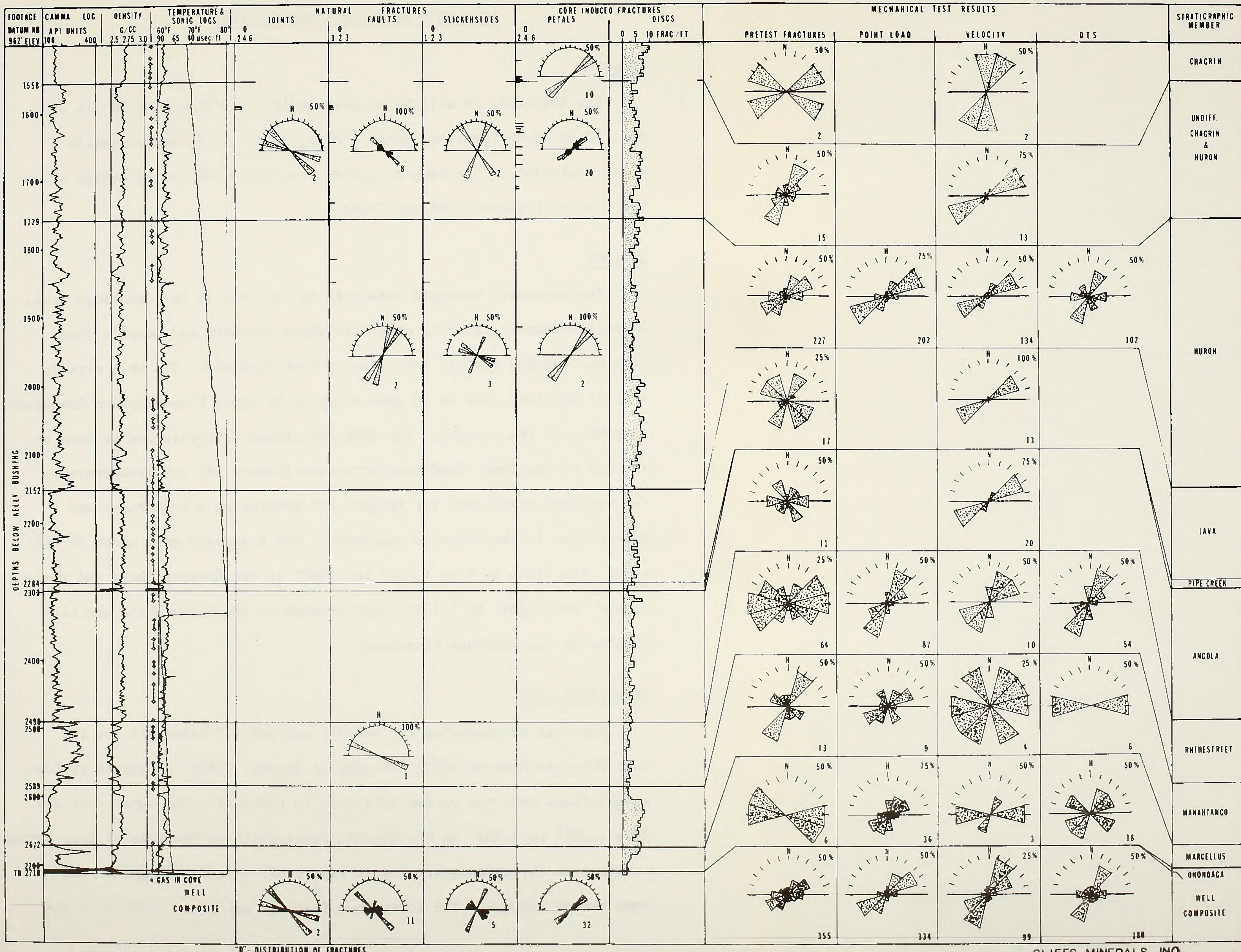


FIGURE 7D E.G.S.P. OHIO 7 WELL SUMMARY.

CLIFFS MINERALS, INC.

EGSP-OHIO #8 (SCHOCKLING #1) WELL

LOCATION

The EGSP-Ohio #8 well is located 960'SL, 510'EL of the NW 1/4 of Sec. 18 of Enoch Township, Noble County, Ohio. It is approximately 5 miles southwest of the town of Caldwell on Route 564 in the center of the county (Figures 1, 8A and Table 1).

GEOLOGY

The prominent geologic structure in the area is the Cambridge Arch, a north-northwest trending anticline whose southern end doesn't join with the Burning Springs Anticline of West Virginia. The well site is east of the fold axis in an area occupied by Upper Pennsylvanian Conemaugh sediments at the surface. The same anticlinal structure can be seen on the top of the Berea Sandstone structure (Figure 8B) but disappears on the Onondaga structural top (Figure 8C) indicating a detachment and deformation in the Devonian sediments. Two intervals were cored in this well. The first is from 1,750' to 2,087' in the Chagrin Shale and the second from 3,085' to 4,151' which started in the Huron Shale and terminated in the Onondaga Limestone.

PRODUCTION DATA

The well is producing 110 mcf/day gas and 1.5 b/day oil for the East Ohio Gas Company (METC Semi-Annual Report, 3/81). A series of foam stimulations were run on two intervals in the well. The upper test was from 2,224' to 2,598' in the Chagrin Shale which is the zone of fluctuating readings on the temperature log in Figure 8F. After stimulation the zone tested 510 MCF. The lower foam fracture was from 3,138' to 3,465'

in the Huron Shale which corresponds to a section where gas shows were visible in the core. This test produced 58 MCF after stimulation.

CORING-INDUCED FRACTURES

A strong petal fracture trend of N10°-20°W is developed in the Chagrin Shale in the upper cored interval. Dropping down 1,000' into the Huron Shale and the second cored interval, the dominant petal fracture strike changes to N50°-60°E, although a small number with the N10°-20°W orientation remain. From the Angola Shale on down, petal fractures display the N50°-60°E orientation. The distinct change in direction of petal orientation indicates a definable stratigraphic anisotropy between the Chagrin Shale and underlying shales. Disc fracture frequency fluctuates throughout the core but is generally very low.

NATURAL FRACTURES

No joints or faults were observed in the upper cored interval (Figure 8F). The lower section, however, showed a strong orientation of E-W vertical joints in the Huron Shale, Hanover Shale, Angola Shale and Rhinestreet Shale. These joints are parallel to the stress that formed the Burning Springs Anticline to the south and were probably formed at the same time. The majority of joints throughout have calcite mineralization with slight dolomite mineralization occurring in the Huron Shale fractures.

Faults occur from the Huron into the Mahantango with most occurring in the Rhinestreet Shale. The five faults in the Huron and Hanover Shales show E-W slickenside trends which parallel the joint system (Figure 8E). In the Rhinestreet, this trend changes to a N50°-60°E

trend of slickensides associated with the seven fault planes logged from 4,000' to 4,001'. Two microfaults in the Mahantango display slickensides bearing E-W and N55°E which parallel both of the above trends. None of the low angle faults were mineralized, but one high angle fault striking N06°W and dipping 53°E contained calcite suggesting it may have been a joint with later movement. The Mellis Diagram (Figure 8D) showing poles to faults indicates detachment E-W and SW-NE, which is normal to the anticlinal axis evident on the Berea Map (Figure 8B).

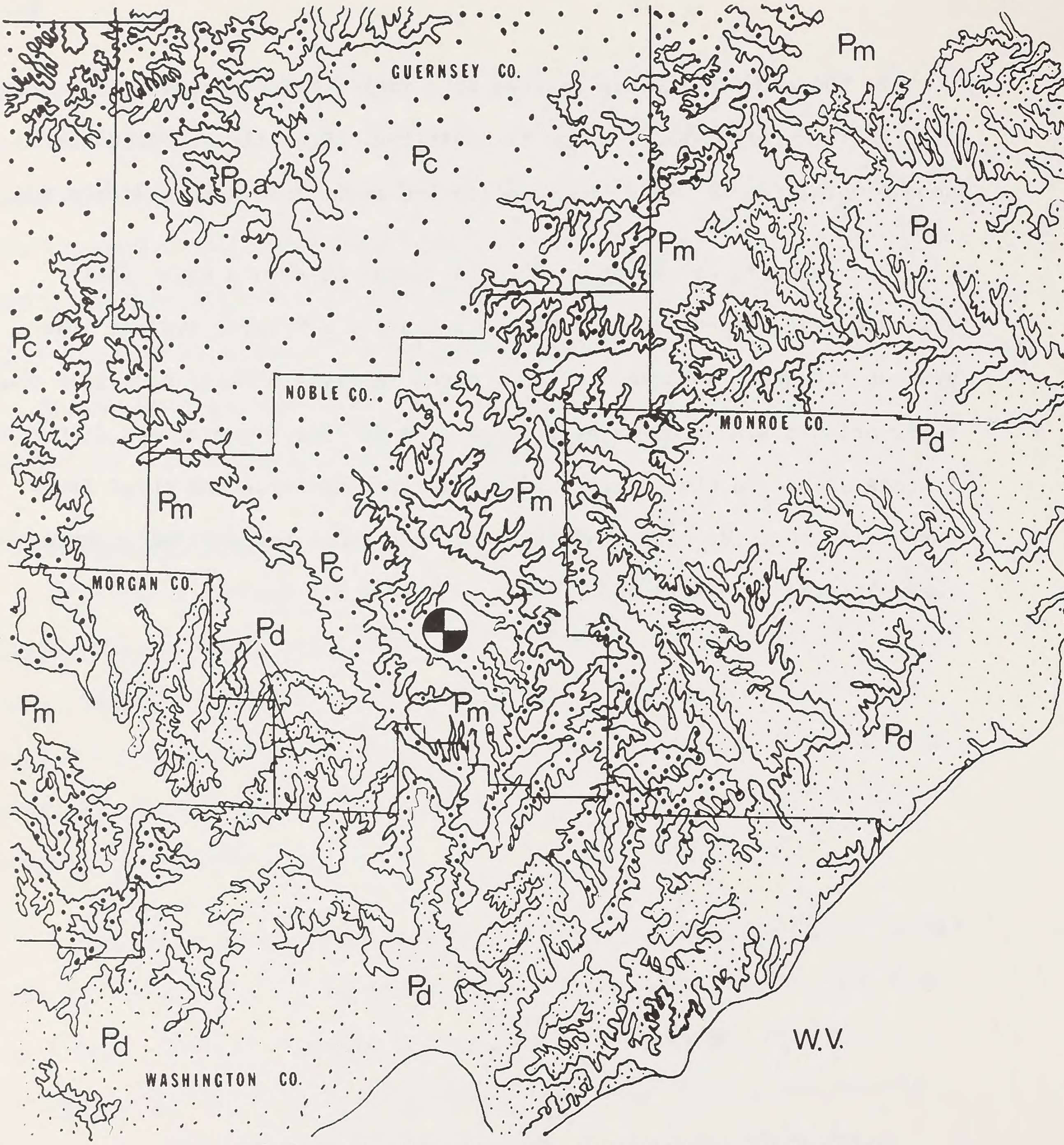
MECHANICAL TEST DATA

Pretest fractures are diverse: a N30°W trend is developed in the Chagrin Shale; below under that a N-S to N30°W trend is developed in the Huron Shale; a N60°W to E-W orientation is noted in the Hanover Shale with a swing to N-S in the Angola Shale; finally a N60°E orientation is prominent in the Rhinestreet Shale through the Mahantango and into the Onondaga Limestone.

Ultrasonic velocity tests show a well-developed orientation throughout the section. A N-S to N60°W trend occurs in the Chagrin, but from that point downward a strong N-S orientation is dominant through the Mahantango Shale. The Marcellus Shale and Onondaga Limestone display N30°W and N60°W maximum velocity directions. Overall, the dominant trend is N-S and the secondary trend is N30°W. Point load tests reflect the velocity tests that are available in the Huron, Rhinestreet, Mahantango and Marcellus Shales, showing the N-S trend and secondary N60°W trend.

If the above tests are related to a rock fabric or stress anisotropy, a definite stratigraphic change is indicated. The pretest fractures show several trends while the velocity and point load data indicate two.

The velocity and point load tests appear to show a rock fabric formed during the compression that created the E-W joint system. The pretest fracture trend in the lower cored interval closely parallels the petal orientations and may be related to a N60°E maximum stress direction in this area. In the Chagrin Shale, pretest fractures and petal fractures also coincide with a N30°E trend that indicates a stratigraphic change in the stress field.



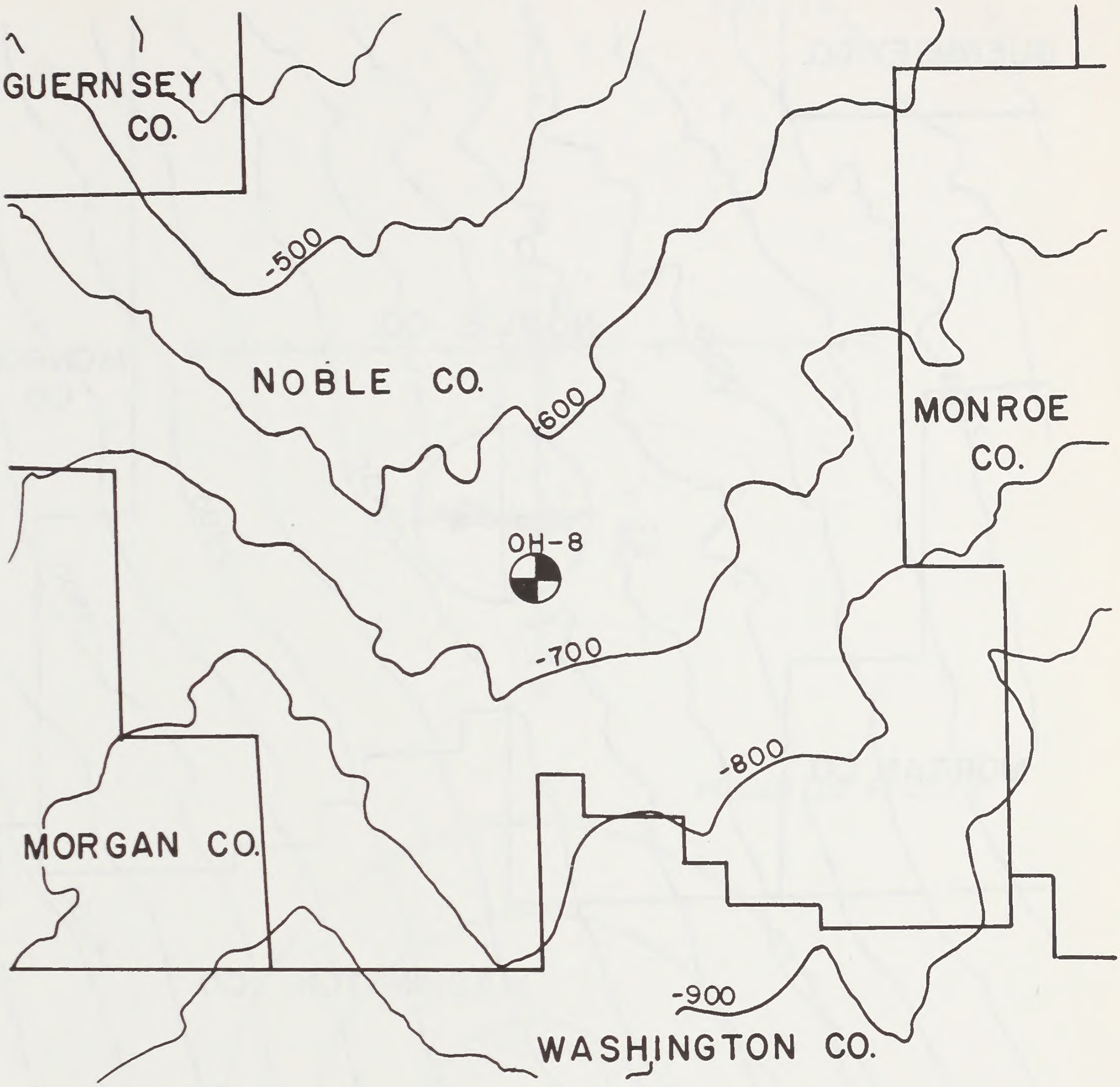
EGSP OHIO-8 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

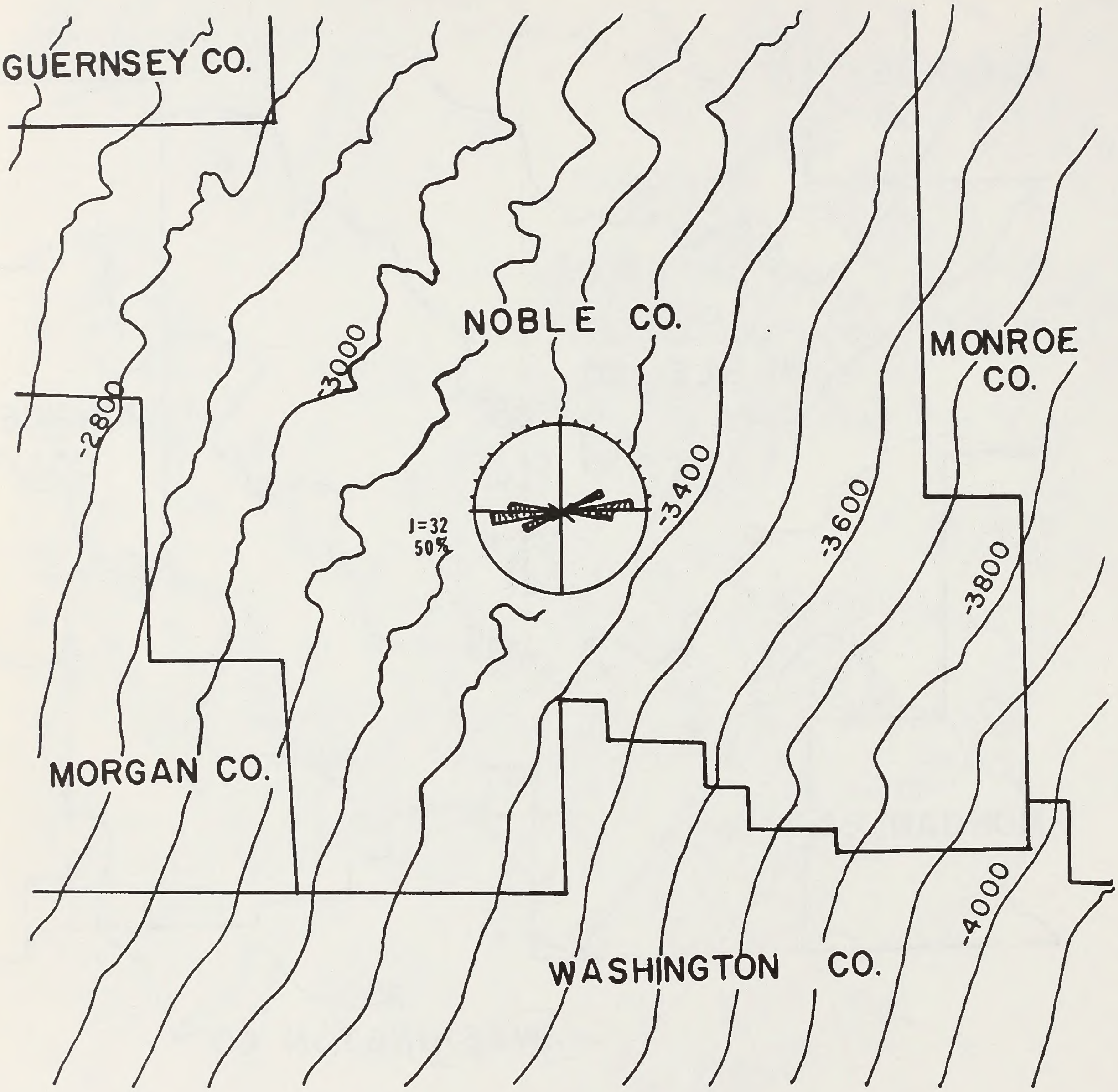
Pd	DUNKARD	Permian
Pm	MONONGAHELA	Pennsylvanian
Pc	CONEMAUGH	Pennsylvanian
Pp,a	POTTSVILLE & ALLEGHENY	Pennsylvanian

SCALE 1:500,000

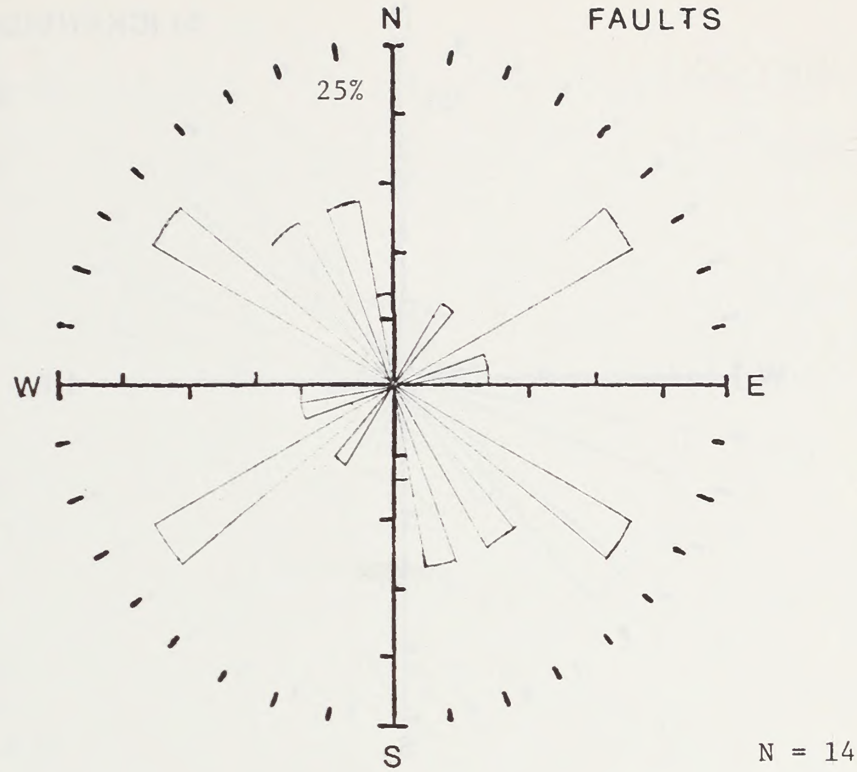
FIGURE 8A

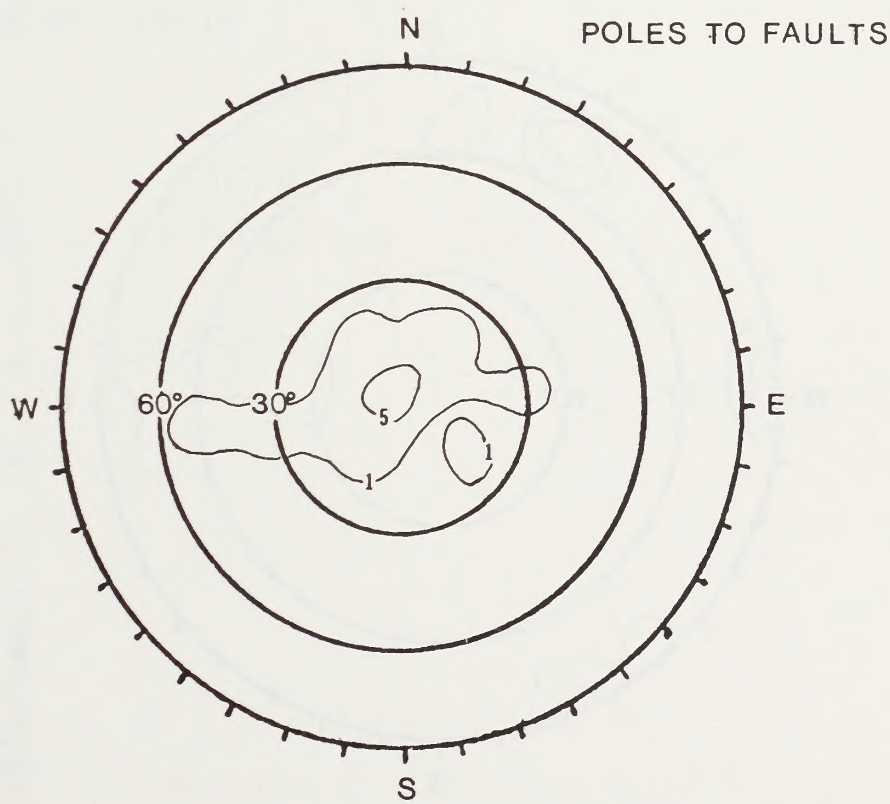


EGSP OHIO-8
STRUCTURAL CONTOURS
TOP OF BEREA SANDSTONE
Scale 1:250,000
FIGURE 8B



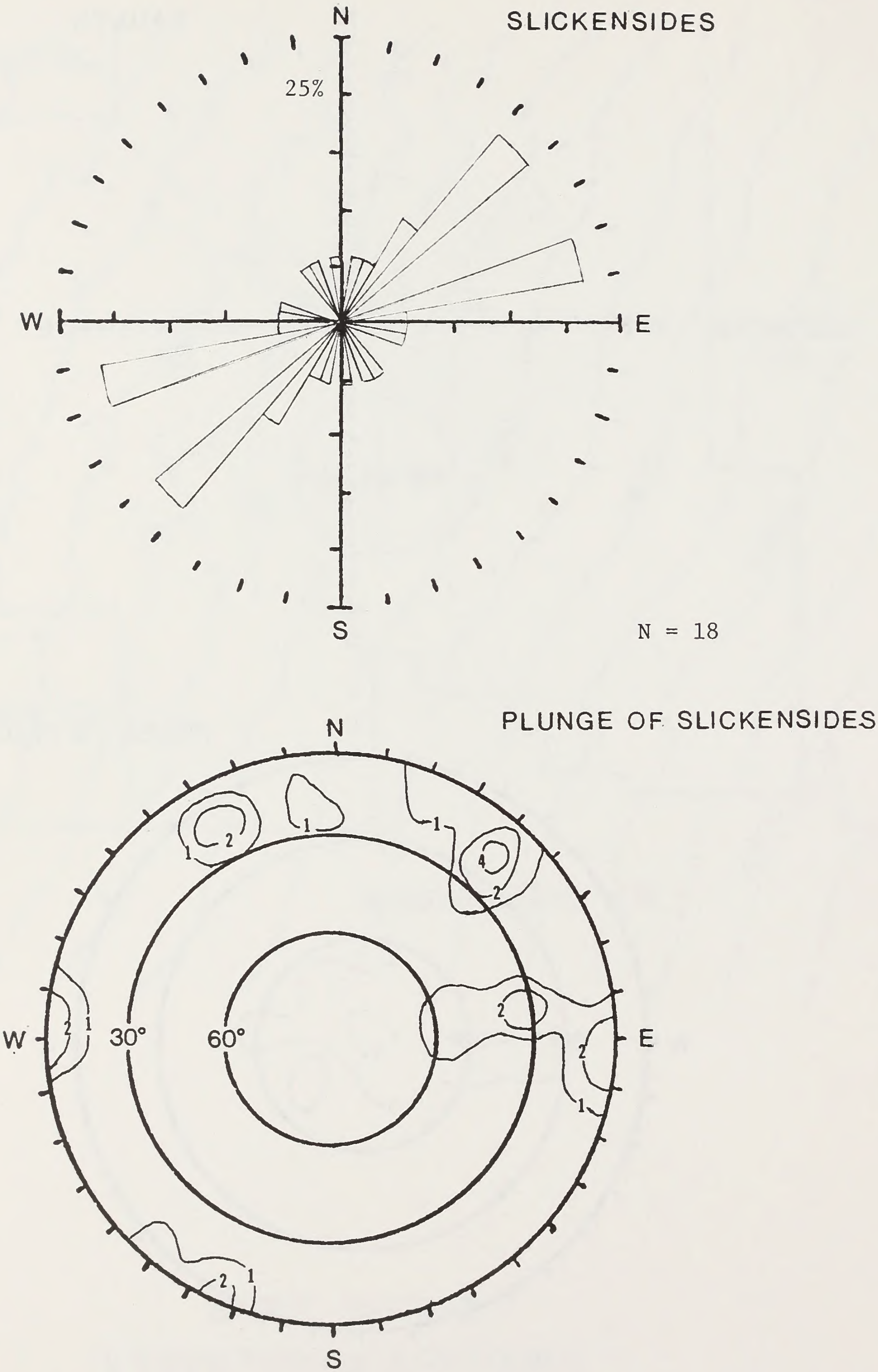
EGSP OHIO-8
STRUCTURAL CONTOURS
TOP OF ONONDAGA LIMESTONE
Scale 1:250,000
FIGURE 8C





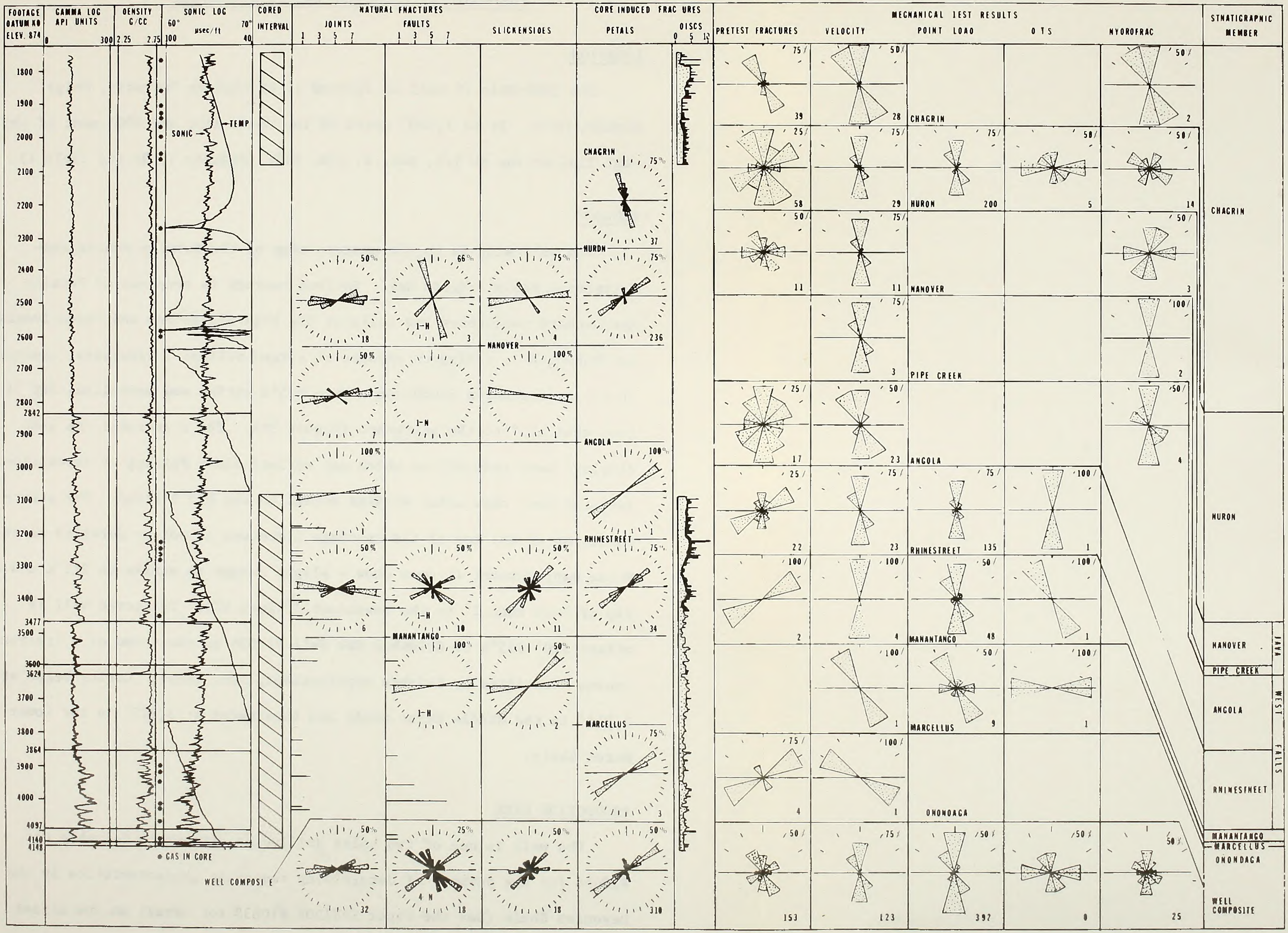
EGSP-OHIO #8

Figure 8D. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.



EGSP-OHIO #8

Figure 8E. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.



"0": DISTRIBUTION OF FRACTURES
H: HORIZONTAL

FIGURE 8F E.G.S.P. OHIO 8 WELL SUMMARY

CLIFFS MINERALS, INC.

EGSP-OHIO #9 (COLUMBIA GAS #10056A) WELL

LOCATION

The EGSP-Ohio #9 well is located in NE Chester Township, Meigs County, Ohio. It is 1,400' north of the south line and 600' west of the east line of the NW 1/4, Sec. 6, T3N, R12W (Figures 1, 9A and Table 1).

GEOLOGY

The well site is on the western edge of the Permian Huntington-Pittsburgh Basin (Figure 9A). Surface bedrock is composed of Permian Age Dunkard sandstones and coals at the high elevations and Pennsylvanian Age Monongahela sediments exposed in stream valleys. Structural contours on top of the Berea Sandstone show a N25°E strike and monoclinal dip of less than 1/2° to the southeast (Figure 9B). The structural top also displays many undulations which may reflect minor folding or depositional features that show axial strikes normal to the N25°E trend. The structural map of the top of the Onondaga Limestone is not as detailed as the Berea map; however it does show a slight change in strike to N15°E and a dip of less than 1° to the southeast (Figure 9C). The cored well is offset 120' S55°W of Columbia Gas Well #10056 on the trend of a fracture system identified by Science Applications, Inc. (SAI). Coring began at 2,914' in the Middle Huron Shale and terminated at 3,372' in the Lower Huron Shale.

PRODUCTION DATA

The well is one of two holes drilled as offsets to Columbia Gas #10056 for the purpose of determining reservoir characteristics in the Devonian Shale (See the paper SPE/DOE #10838 for detail on the offset

well tests). Geophysical logs indicate a gas-producing area 20' below T.D. in the Lower Huron Shale that is probably associated with an open fracture system.

CORING-INDUCED FRACTURES

An unusually large number of petal fractures occurs in this core. A total of 898 fractures was recorded with 238 striking N60°-70°E in the Middle Huron and 660 striking N70°-80°E in the Lower Huron Shales (Figure 9D). Disc fracture frequency is low for both members.

NATURAL FRACTURES

Joints:

A total of thirteen joints occurs in the Lower Huron Shale. The upper section from 3,000' to 3,300' shows eight vertical joints trending N70°-80°E and one vertical joint striking N64°E. The lower section from 3,349' to 3,361' displays four fractures striking N68°E to N74°E and dipping at high angles, approximately 70°NW and SW. The two lowermost joints are mineralized with minor calcite.

The results of the offset well study show a N55°E fracture trend that is responsible for the porosity of the gas producing horizons of the shale, and that the fractures are limited to specific stratigraphic levels that are not connected vertically but are connected horizontally over significant distances.

A likely conclusion is that this area has been and still is being subjected to a significant horizontal stress field that produced the strong joint trend and is in part responsible for the strong coring

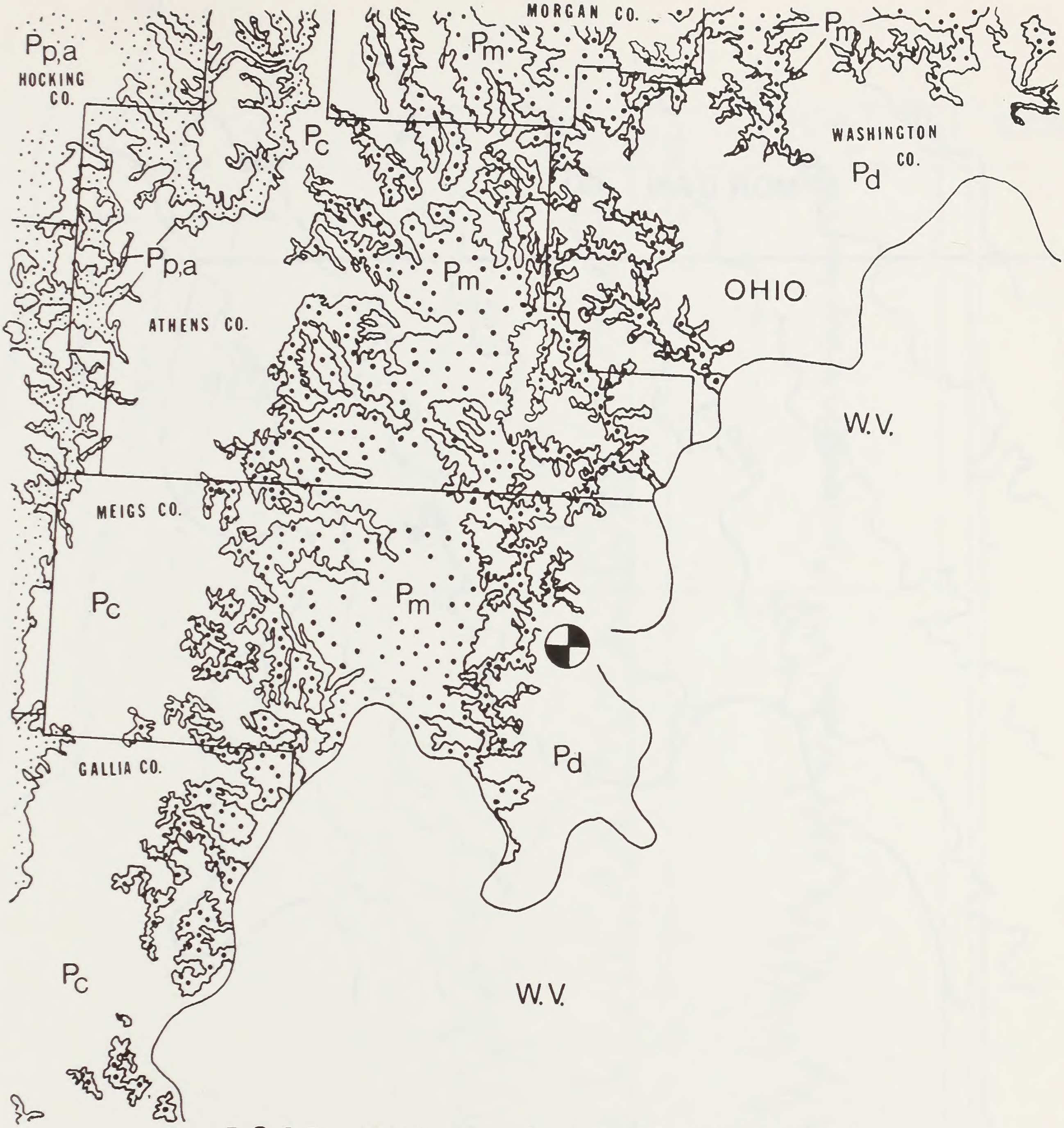
induced fracture trend. The vertical limitation of fractures defined by reservoir testing indicates that the confinement is probably the result of differing physical characteristics of adjacent rock zones and their resultant behavior in the stress field.

Faults and Slickensides:

Only one microfault is present at 3,183' in the Lower Huron Shale. It strikes N75°E and dips 25°SE with slickensides trending S35°E and plunging 23°.

MECHANICAL TEST DATA

Due to the large number of coring-induced fractures, it was not feasible to obtain a sufficient number of samples for mechanical tests.



E.G.S.P. OHIO-9 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

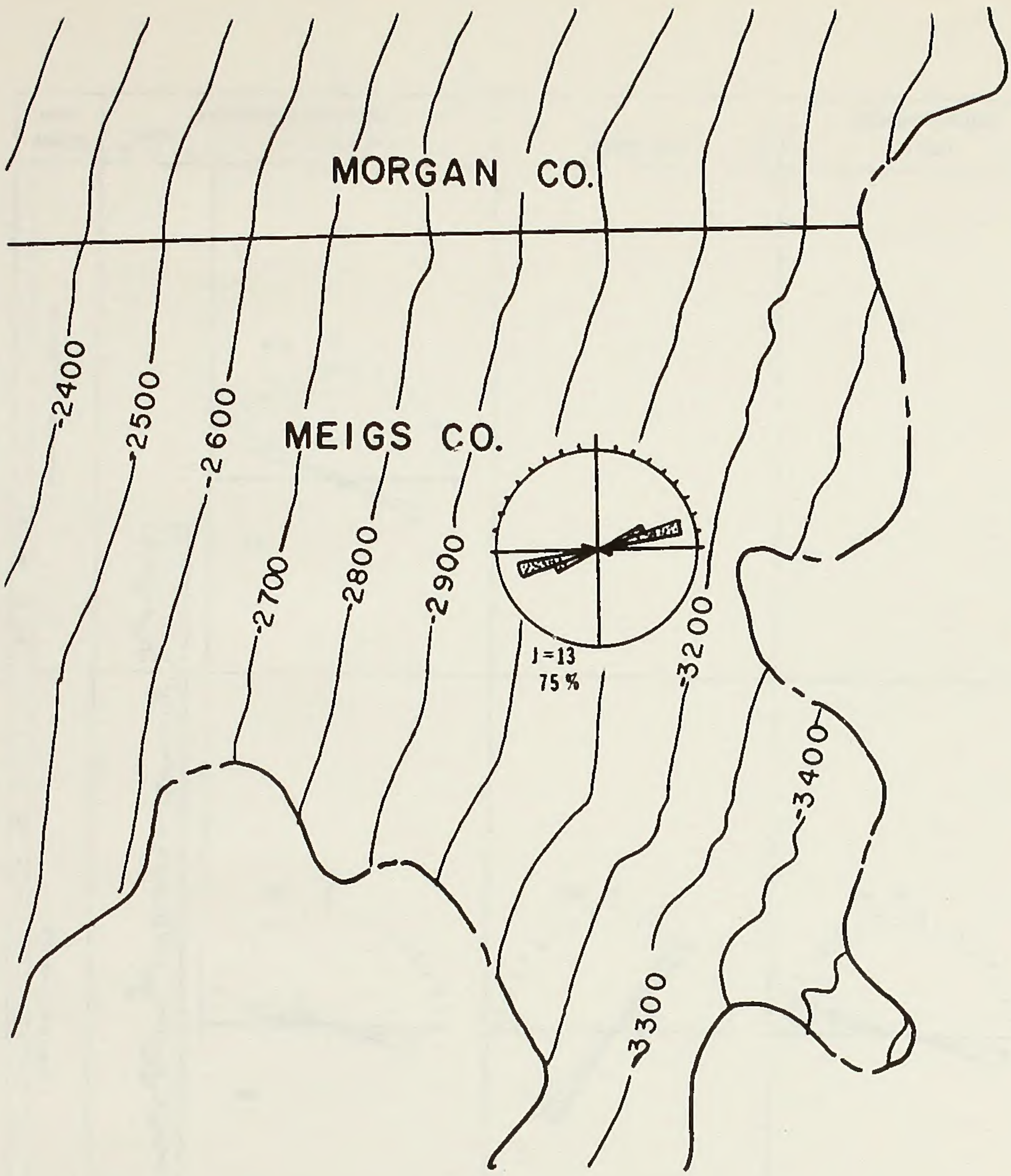
LEGEND

Pd	DUNKARD	Permian
Pm	MONONGAHELA	Pennsylvanian
Pc	CONEMAUGH	
Pp,a	POTTSVILLE & ALLEGHENY	

SCALE 1:500,000

FIGURE 9A

EGSP OHIO-9
STRUCTURAL CONTOURS
TOP OF BEREA SANDSTONE
Scale 1:250,000
FIGURE 9B



EGSP OHIO-9
STRUCTURAL CONTOURS
TOP OF ONONDAGA LIMESTONE
Scale 1:250,000
FIGURE 9C

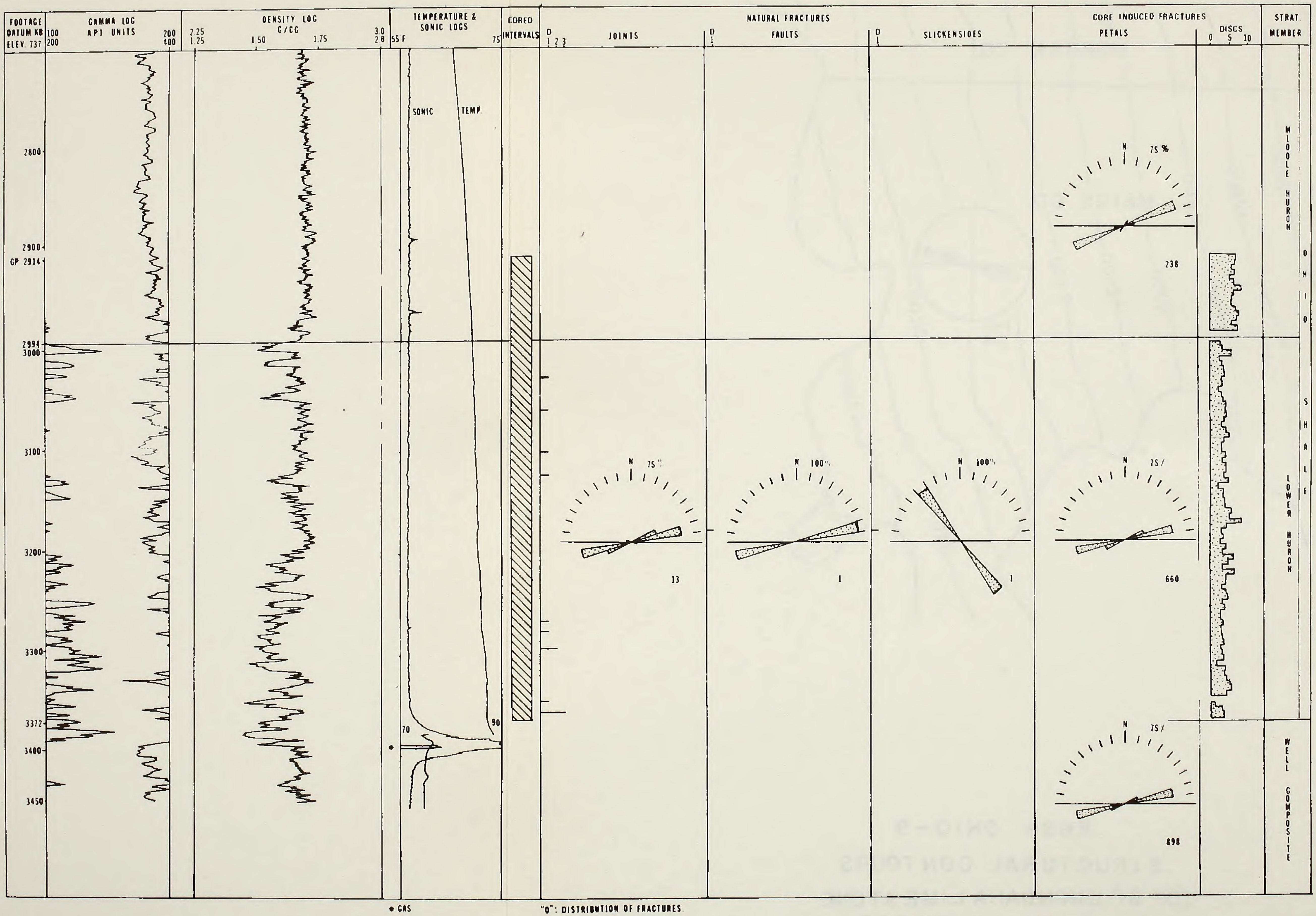


FIGURE 90 E.G.S.P. OHIO 9 WELL SUMMARY

CLIFFS MINERALS, INC.

APPENDIX D

PENNSYLVANIA EGSP WELLS

PENNSYLVANIA #1: (M. R. EX. #1) WELL
PENNSYLVANIA #2: (C. E. POWER SYSTEMS #1) WELL
PENNSYLVANIA #3: (PRESQUE ISLE STATE PARK #1) WELL
PENNSYLVANIA #4: (GLENN McCALL #5) WELL
PENNSYLVANIA #5: (C. SOKEVITZ #1) WELL

EGSP-PENNSYLVANIA #1 (M. R. EX. #1) WELL

LOCATION

The EGSP-Pennsylvania #1 well is located ten miles south of the city of Bradford in Lafayette Township, McKean County, Pennsylvania (Figures 1, 1A and Table 1).

GEOLOGY

The well site is located in an area of rugged topography with 500' differences in elevations a common feature. Bedrock consists of Permian, Mississippian, Pennsylvanian and Devonian sediments that are relatively undeformed. The detailed geological structure maps of the Middle Devonian show a parallel series of NE trending faults, NW of the well site which probably extend through the area but are not well defined due to lack of well control. Overall the Devonian strata dips and thickens to the south into the deep part of the Appalachian Basin (Figures 1A through 1F).

A total of 741' of core was retrieved from two intervals in the well. The first is across the Angola-Rhinestreet Shale contact from 3,470' to 3,528'. The second begins at 4,530' in the Middlesex Member of the Sonyea Formation and terminates at 7,213.3' in the Marcellus Shale Member of the Hamilton Group.

SURFACE FRACTURE DATA

In a study of the Bradford Oil field, a series of surface fracture sites were measured on the periphery of the producing area. The lithology of each site is a sandstone (the Salamanca Sandstone of the Cattaraugus Formation) bounded by shales of Upper Devonian Age. Two

significant trends are evident: one NW, the transverse joint set, and a second NE, or longitudinal set, which is normal to the first (Figure 1A). These surface joint trends are paralleled by the joints in Pennsylvania #1 measured in the Sonyea Formation through the Marcellus Shales of the Upper and Middle Devonian strata (Figure 1A). These two trends are also parallel to the major systematic joint systems measured in New York and are directly related to the fold axes of the Appalachian Basin.

PRODUCTION DATA

No gas is being produced from the Devonian section of this well. The well lies between two lobes of the Bradford Oil Field and has not been stimulated to develop a reservoir system.

CORING-INDUCED FRACTURES

There are no petal fractures in the Pennsylvania #1 core. The majority of the induced fractures are the disc type which display high frequencies per foot in the Genesee and Lower Hamilton Formations outlining the more fissile shales (Figure 1I).

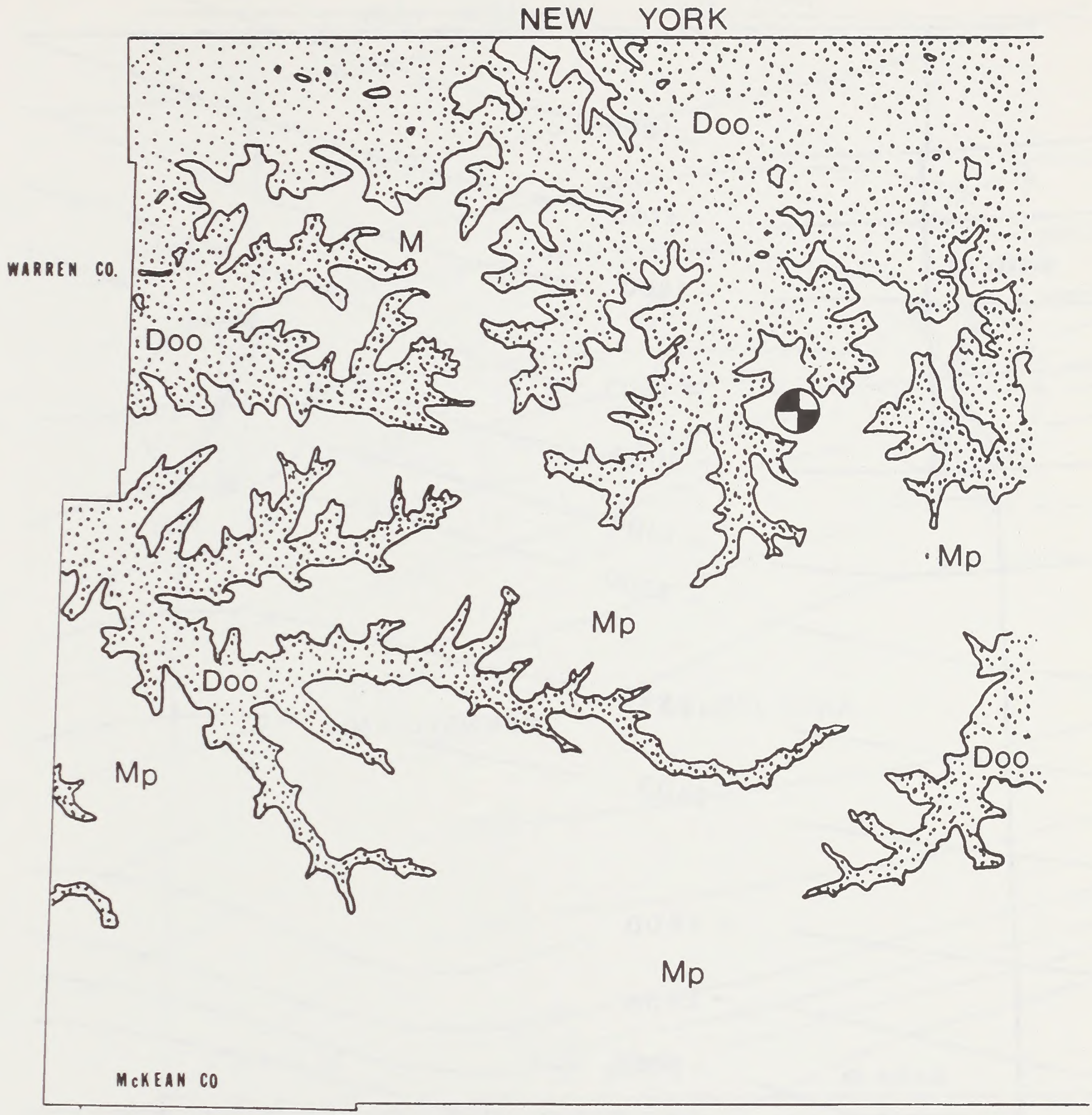
NATURAL FRACTURES

Joints occur throughout the cored intervals (Figure 1I). All the fractures are closed and mineralized with calcite and are usually found in or near the lime concretions in the shales. The dominant joint trend for the well is N20°-30°W and is normal to the secondary N70°-80°E set. These trends are parallel to surface joints measured near the well site (Figure 1A). The joint sets are directly associated with the folding and translate into extension and longitudinal joints normal and parallel to the fold axes.

Faults show a N70°-80°E strike with a corresponding movement indicated by the slickensides from North to N30°W (Figure 1H). This trend is directly associated with the maximum horizontal stresses expected during the Allegheny Orogeny. The concentration of faults in the Marcellus indicates that this fissile organic shale member acted as a décollement zone during deformation. Projections of poles to the fault planes (Figure 1G) and slickenside trends and plunge (Figure 1H) projected on Schmidt nets show the low angle of faulting indicating bedding plane faulting associated with décollement horizons.

MECHANICAL TEST RESULTS

Well composites of all the mechanical test results indicate a strong N60°E anisotropy. This N60°E trend correlates with earlier work in the Bradford Oil Field by W. K. Overby, Jr. where hydraulic fracture analysis of several wells shows a N70°E induced fracture development. A notable feature of this well is that the mechanical test data is parallel to the induced fracture direction that stimulation treatment generates in this area.



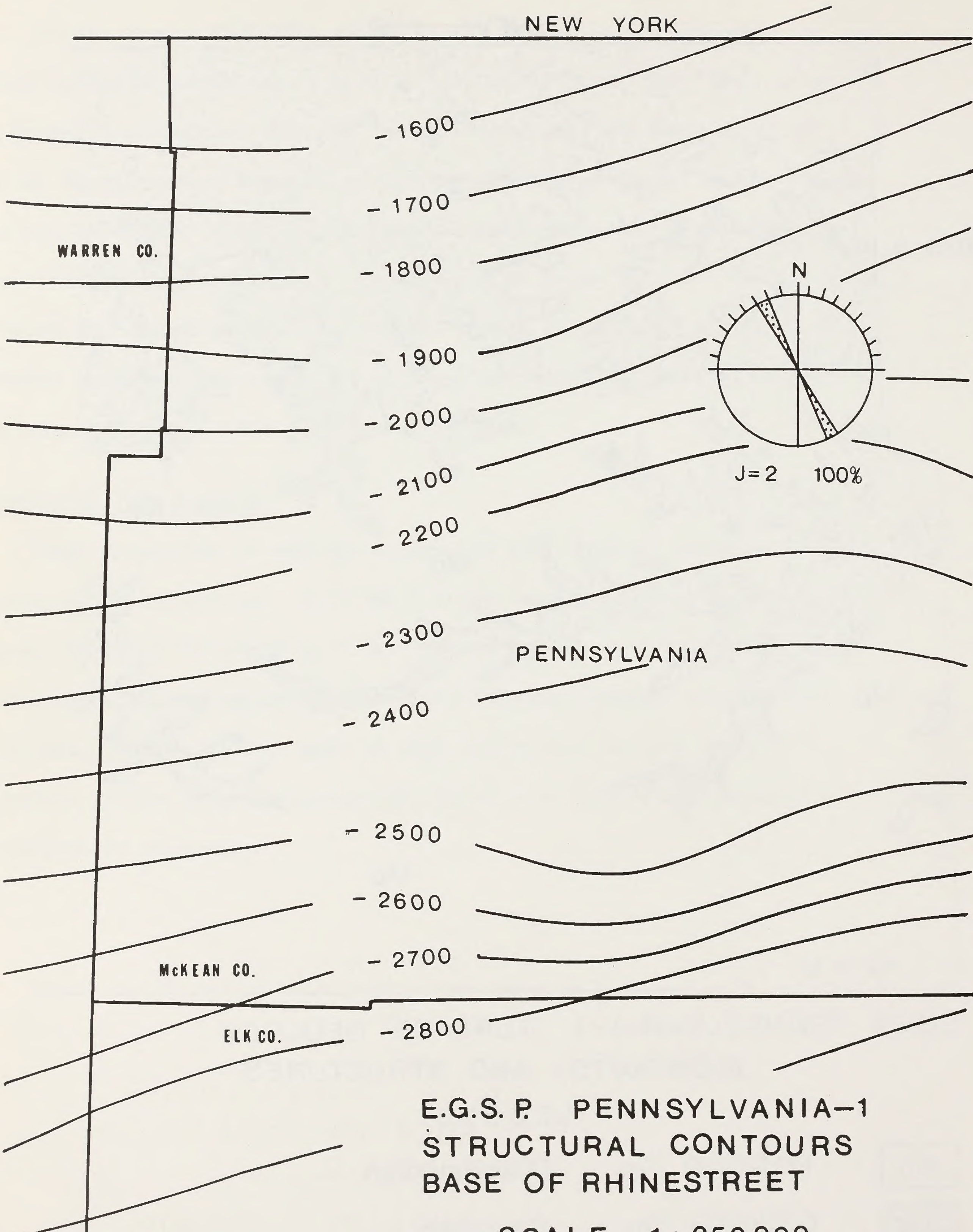
E.G.S.P. PENNSYLVANIA-1 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

Mp	POCONO Gp.	Mississippian
Doo	OSWAYO Fm.	Devonian

SCALE 1 : 250,000

FIGURE 1A

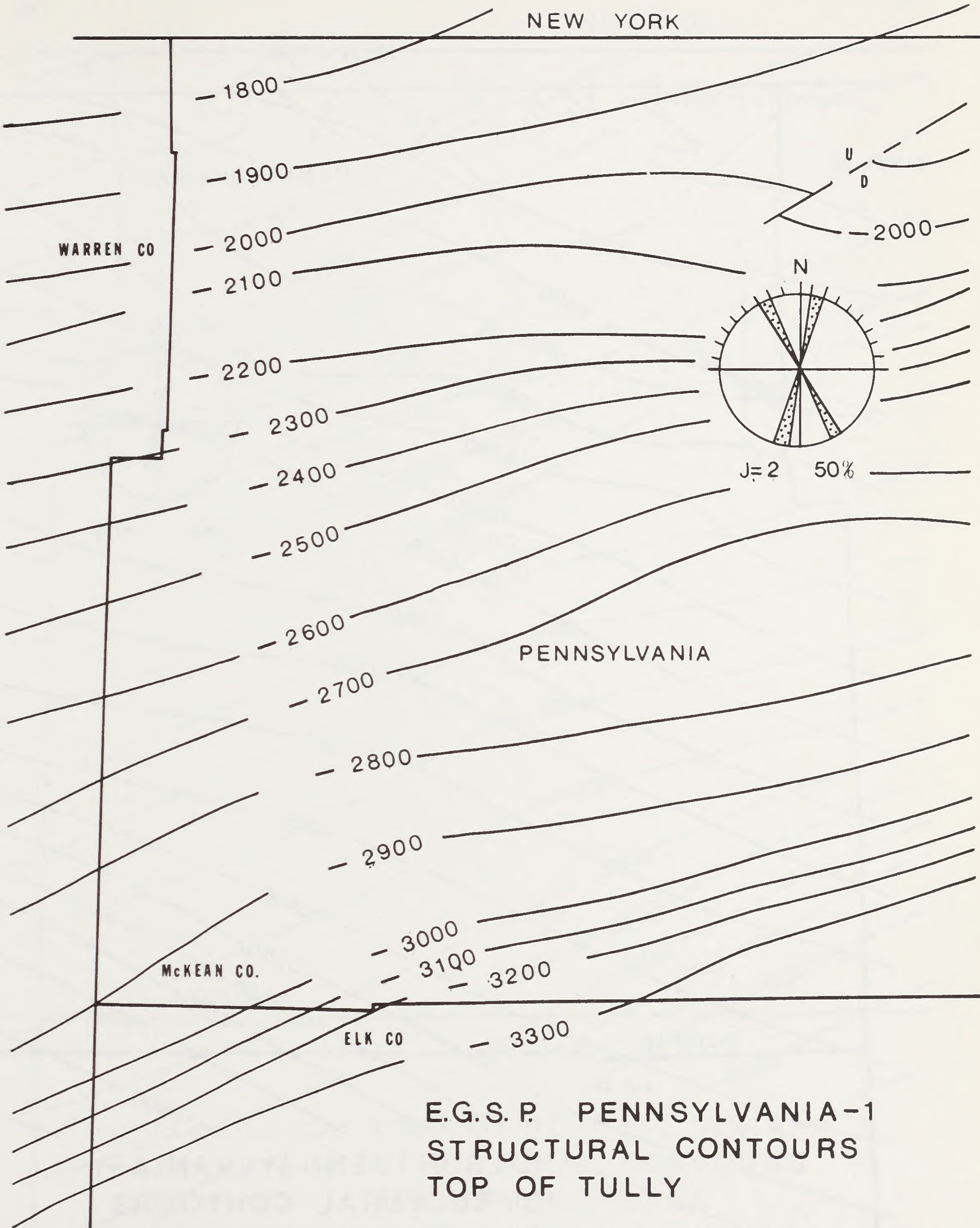


E.G.S.P. PENNSYLVANIA-1
STRUCTURAL CONTOURS
BASE OF RHINESTREET

SCALE 1 : 250,000

ROSE DIAGRAM : RHINESTREET

FIGURE 1B

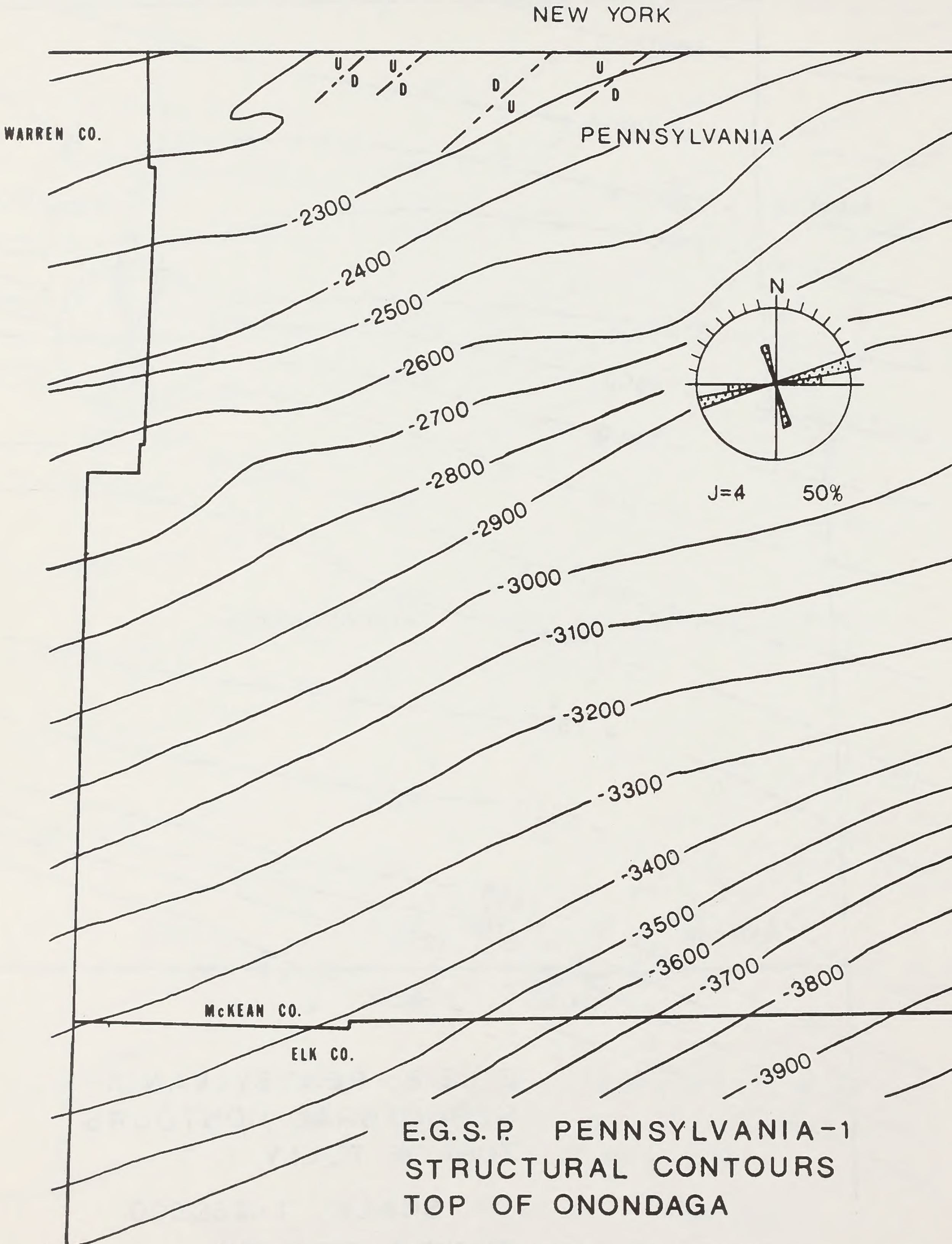


E.G.S.P. PENNSYLVANIA-1
STRUCTURAL CONTOURS
TOP OF TULLY

SCALE 1:250,000

ROSE DIAGRAM : GENESEE UNDIFF.

FIGURE 1C

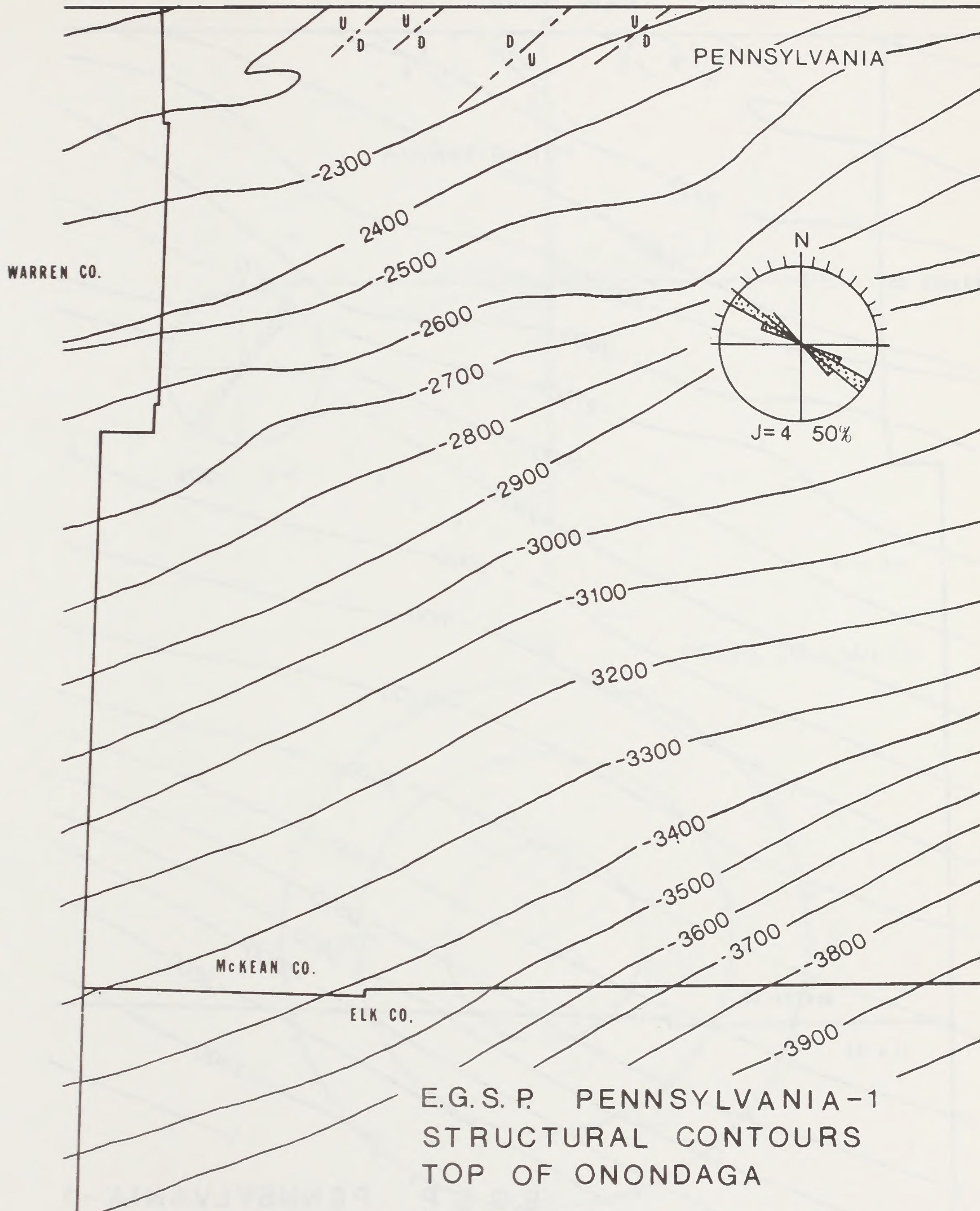


E.G.S.P. PENNSYLVANIA-1
STRUCTURAL CONTOURS
TOP OF ONONDAGA

SCALE 1: 250,000

ROSE DIAGRAM : MARCELLUS

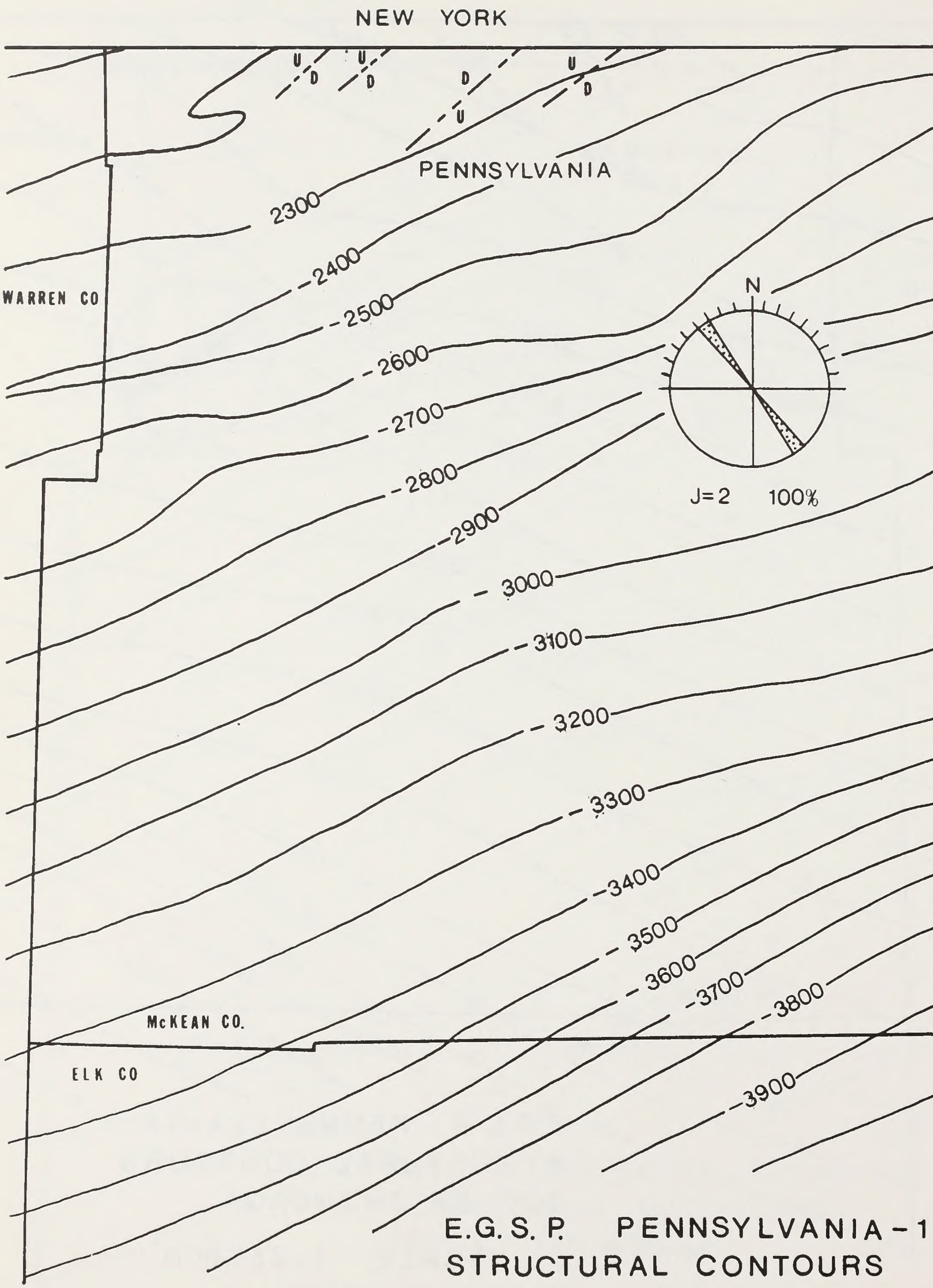
FIGURE 1D



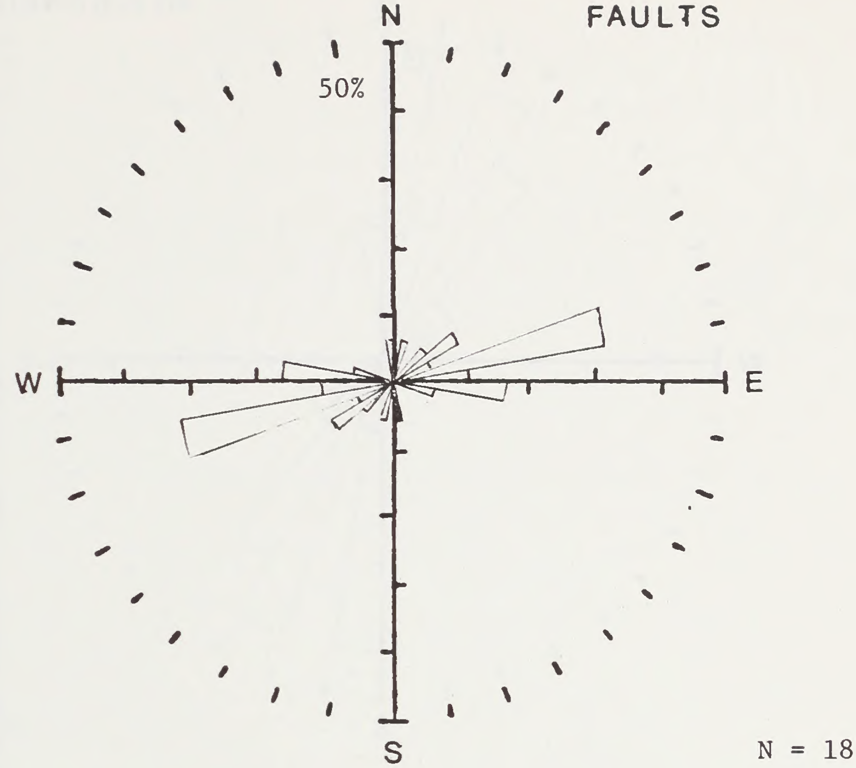
E.G.S.P. PENNSYLVANIA-1
STRUCTURAL CONTOURS
TOP OF ONONDAGA

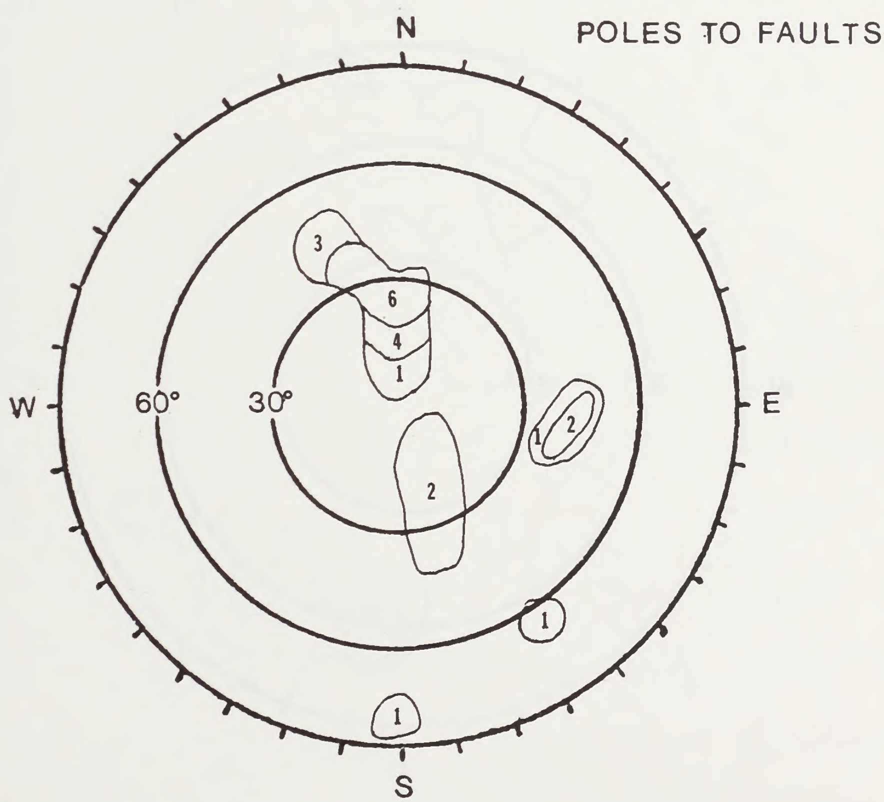
SCALE 1:250,000

ROSE DIAGRAM: LUDLOWVILLE
FIGURE 1E



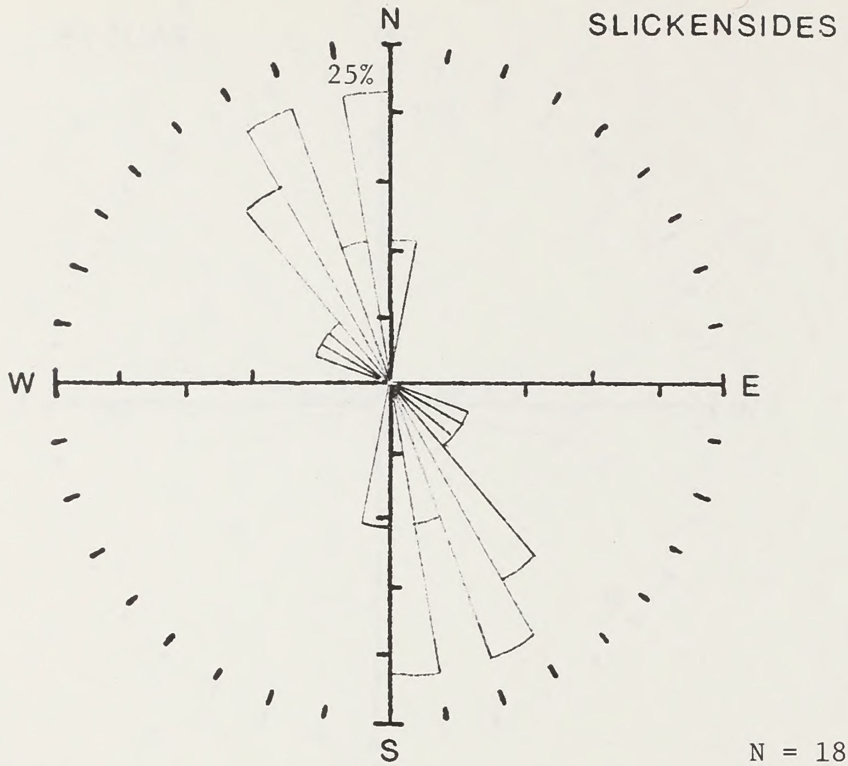
E.G.S.P. PENNSYLVANIA-1
STRUCTURAL CONTOURS
TOP OF ONONDAGA
SCALE 1:250,000
ROSE DIAGRAM : SKANEATELES
FIGURE 1F

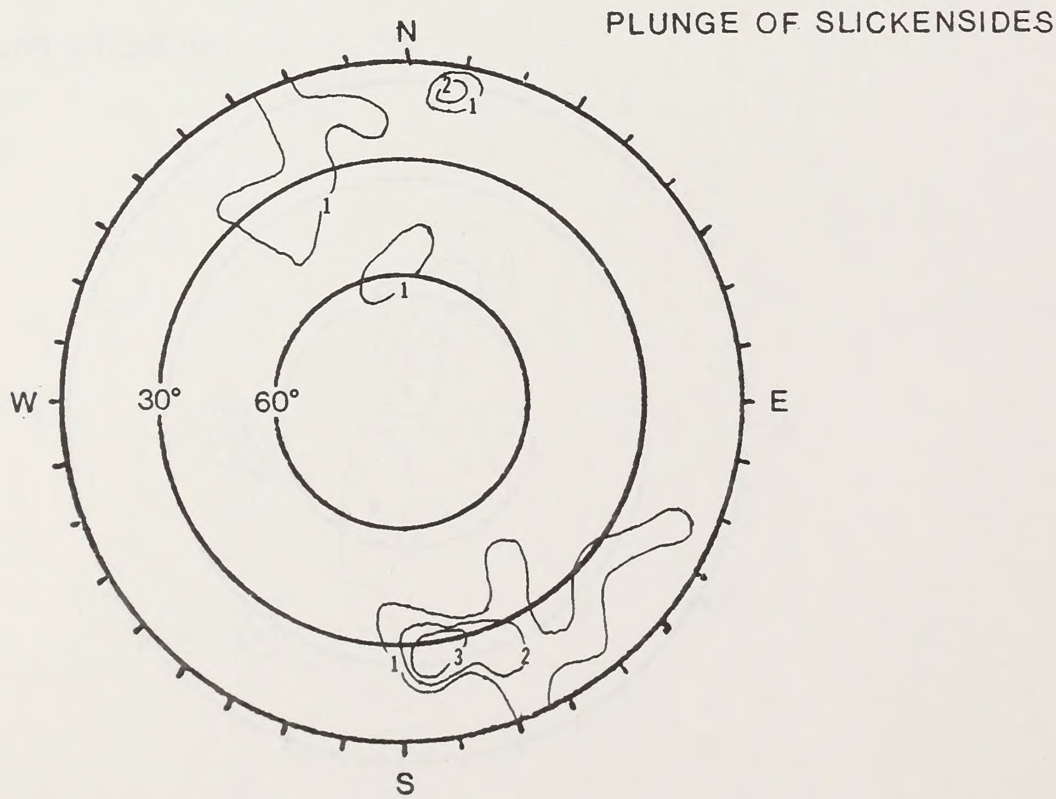




EGSP-PENNSYLVANIA #1

Figure 1G. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.





<u>EGSP-PENNSYLVANIA #1</u>

Figure 1H. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.

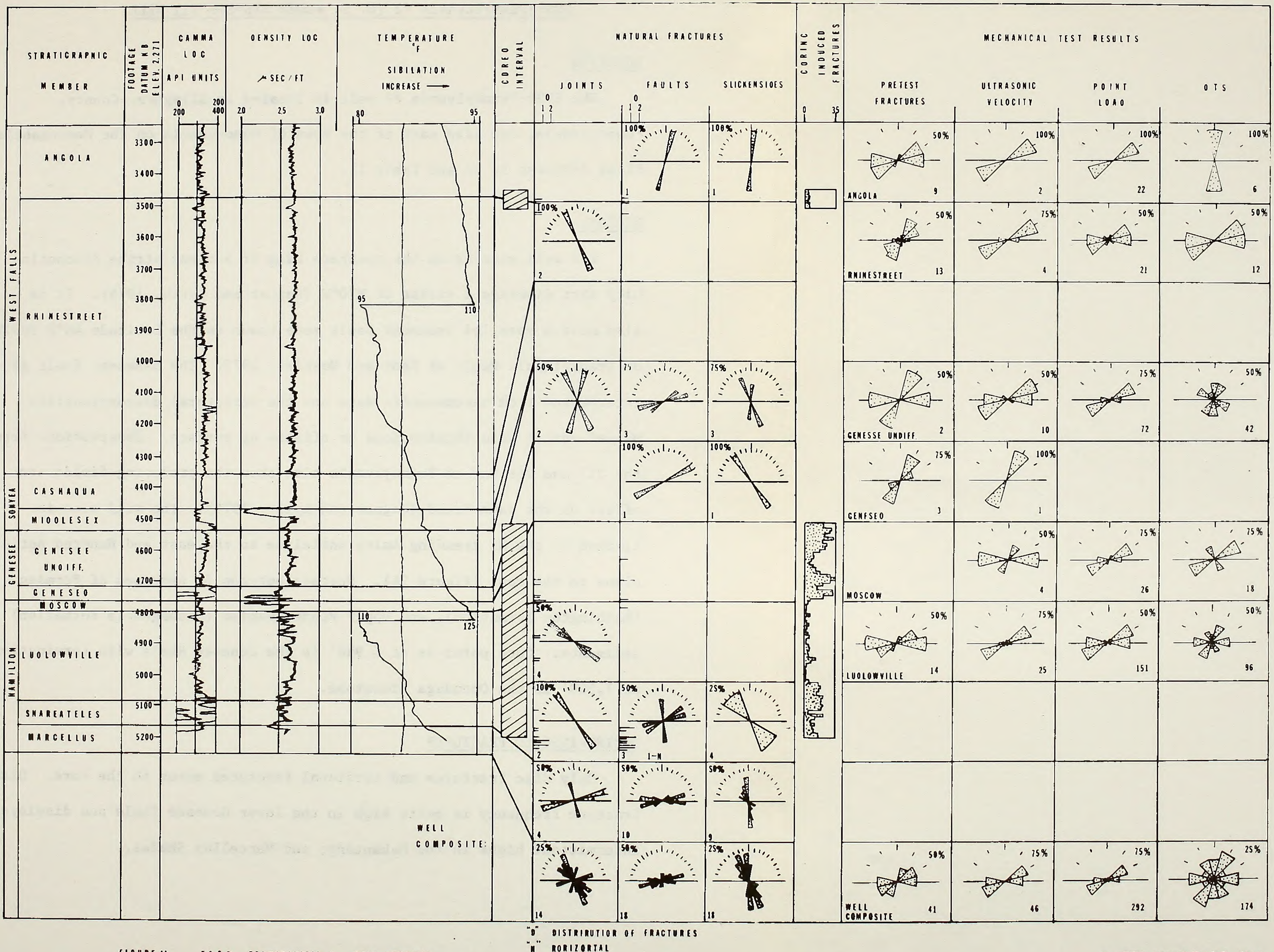


FIGURE 11 EGSP PENNSYLVANIA 1 WELL SUMMARY

EGSP-PENNSYLVANIA #2 (C. E. POWER SYSTEMS #1) WELL

LOCATION

The EGSP-Pennsylvania #2 well is located in Allegheny County, Pennsylvania, one mile east of the town of Monongahela on the Monongahela River (Figures 1, 2A and Table 1).

GEOLOGY

The well site is on the southern edge of a cross-strike discontinuity that displays a strike of N70°W (Wagner and Lytle, 1976). It is also near a parallel basement fault zone known as the Latitude 40°N Fault or Transylvania Fault of Root and Hoskins, 1977. The basement fault is interpreted from aeromagnetic data and the structural discontinuities mapped across fold terminations or offsets at surface. Observations from the Oil and Gas Map of Pennsylvania also show the producing fields are offset on the same trend (Wagner and Lytle, 1976). The well site is flanked by the NE trending Amity Anticline to the east and Hundred Anticline to the west (Figure 2A). Surface outcrop is composed of Permian (Washington Formation), and Upper Pennsylvanian (Monongahela Formation) sediments. Core point is at 6,950' in the Genesee Shale with termination at 7,500' in the Onondaga Limestone.

CORING-INDUCED FRACTURES

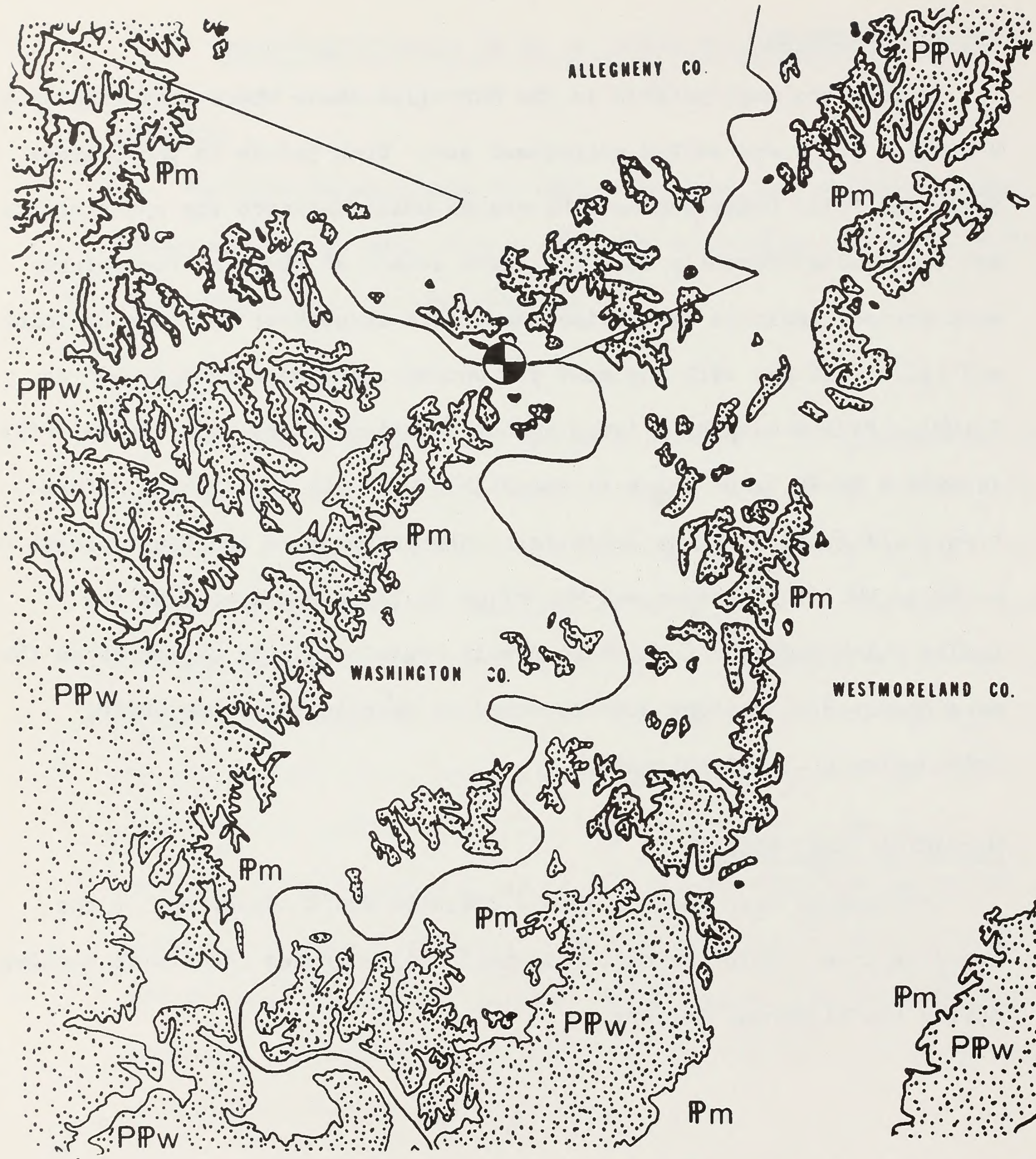
Only disc fractures and torsional fractures occur in the core. Disc fracture frequency is quite high in the lower Genesee Shale and displays intermittent highs in the Mahantango and Marcellus Shales.

NATURAL FRACTURES

Joints are most notable in the Marcellus Shale where they display a N-S major trend and an E-W orthogonal set. Four joints in the Genesee Shale and Tully Limestone have NW trends which indicate the upper strata was stressed differently than the lower strata at the time the joints were formed. Calcite mineralization occurs throughout the core as joint and fault fillings with the most pronounced occurrence from 6,950' to 7,100'. Faults display a large number of orientations with the majority showing a SW-NE trend which is compatible with the Appalachian deformation. Slickenside trends definitely show movement on the fault planes to be SE to NW. The Genesee and Marcellus Shales contain most of the faults which suggests that these highly organic fissile shales above the more competent limestone members acted as décollement zones during deformation of the Appalachians.

MECHANICAL TEST RESULTS

Mechanical test results show a definite N30°E anisotropy in the cored section. This dominant orientation illustrates the fabric developed during the Allegheny Orogeny.



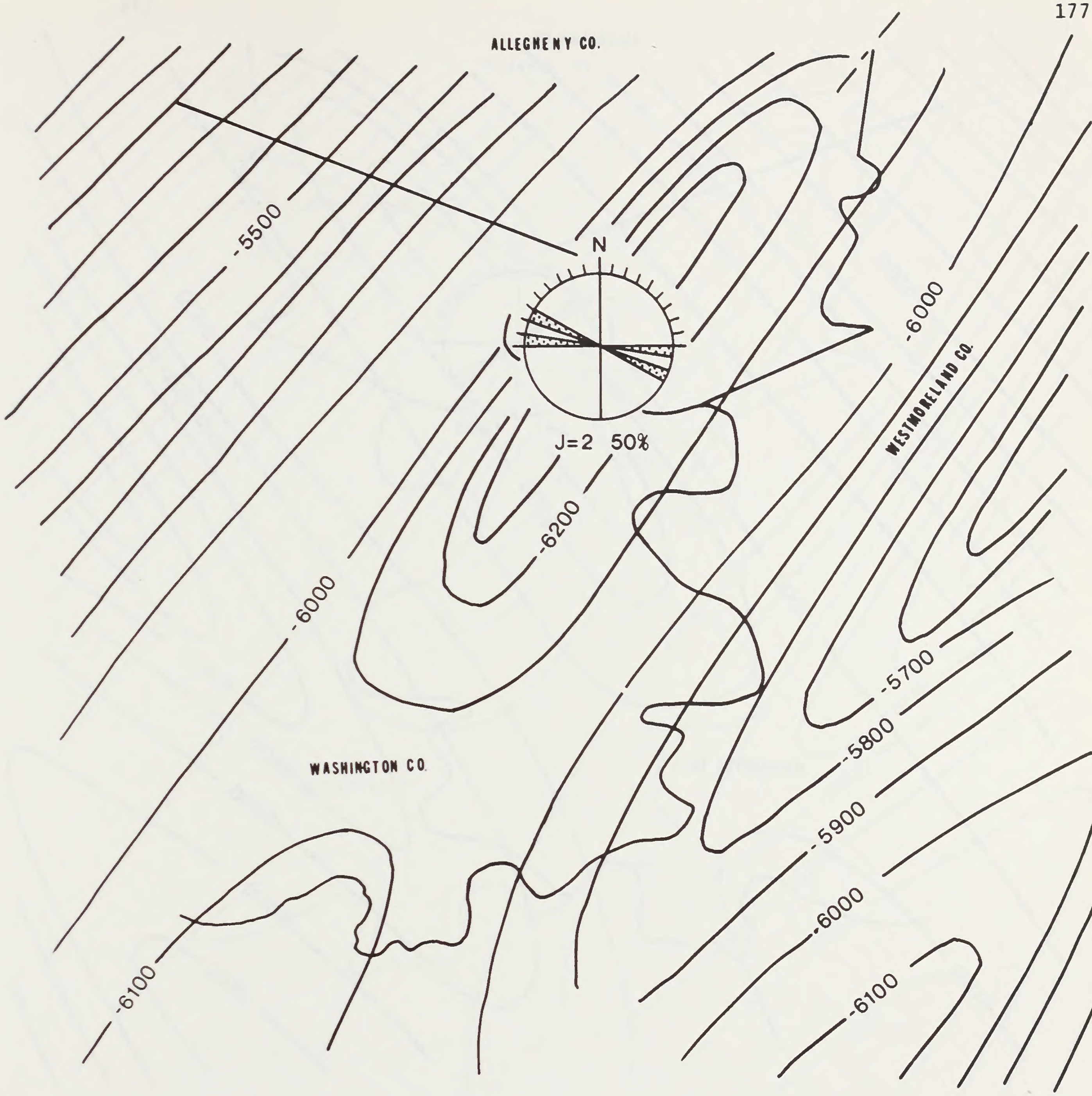
E.G.S.P. PENNSYLVANIA-2 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

PPw	WASHINGTON Fm. Pennsylvanian & Permian
Pm	MONONGAHELA Fm. Pennsylvanian

SCALE 1 : 250,000

FIGURE 2A



E.G.S.P. PENNSYLVANIA-2

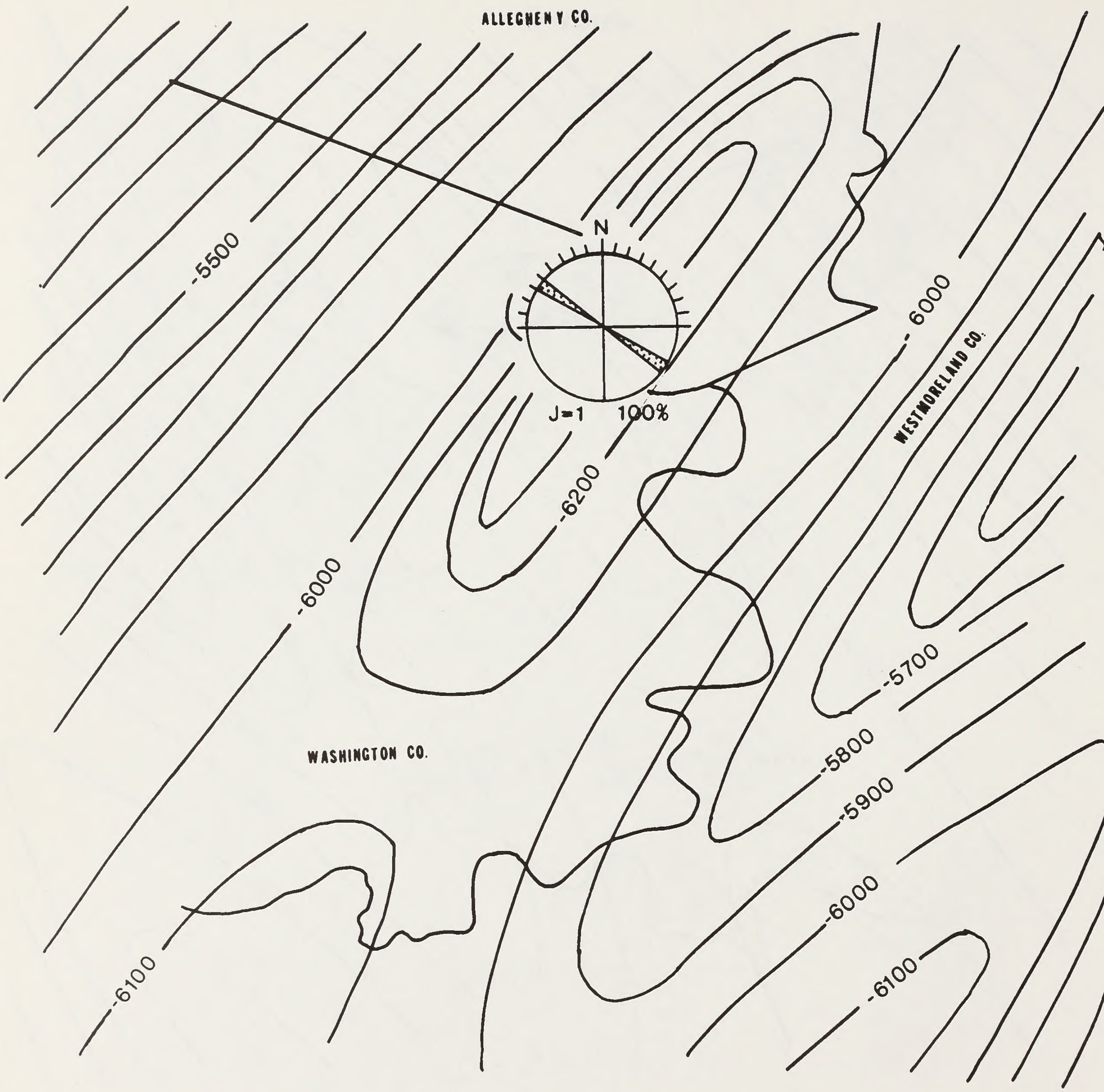
STRUCTURAL CONTOURS

TOP OF TULLY

SCALE 1:250,000

FIGURE 2B

ROSE DIAGRAM: UNDIFFERENTIATED GENESEE



E.G.S.P. PENNSYLVANIA-2

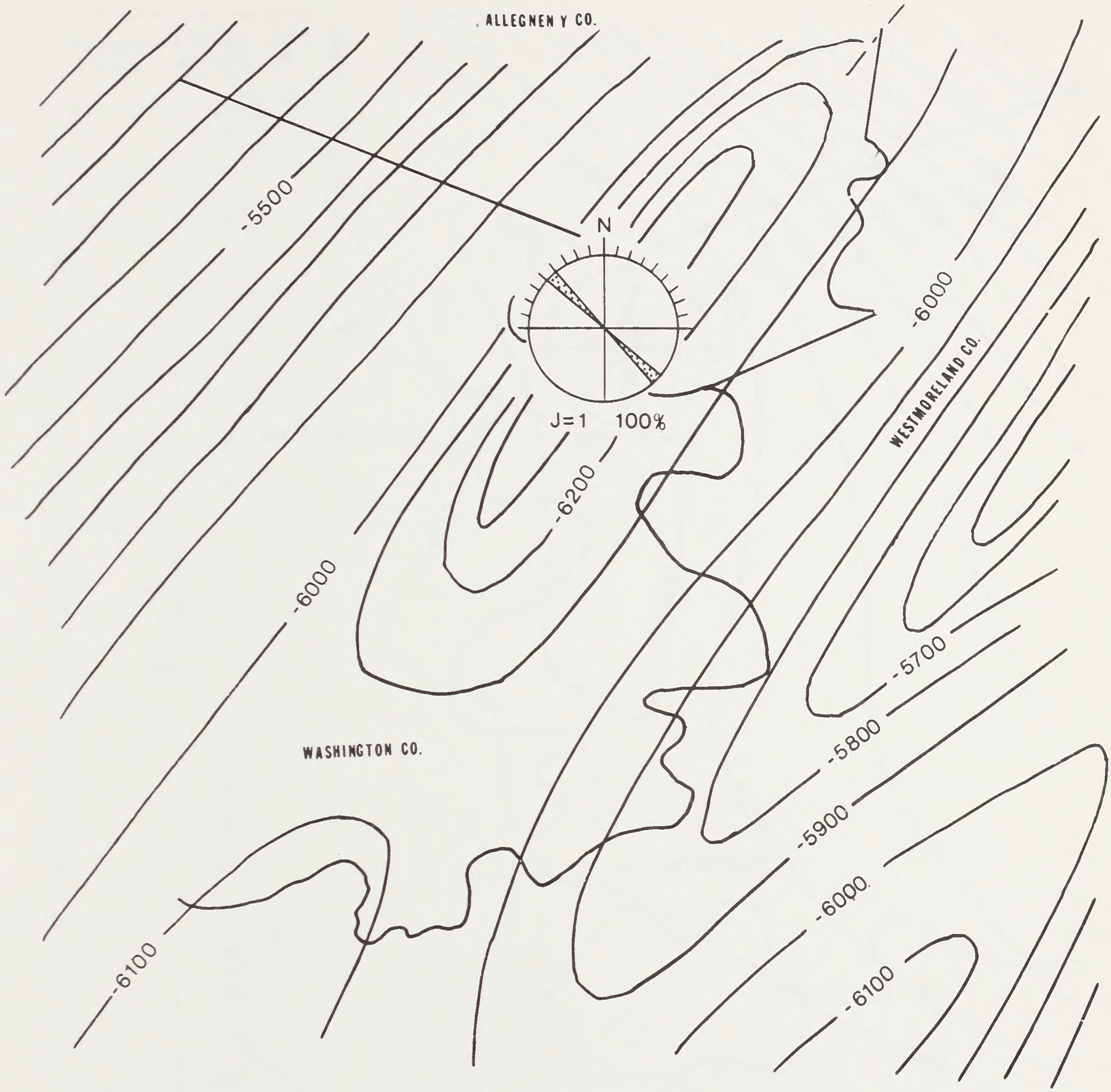
STRUCTURAL CONTOURS

TOP OF TULLY

SCALE 1:250,000

FIGURE 2C

ROSE DIAGRAM: GENESEO



E.G.S.P. PENNSYLVANIA-2

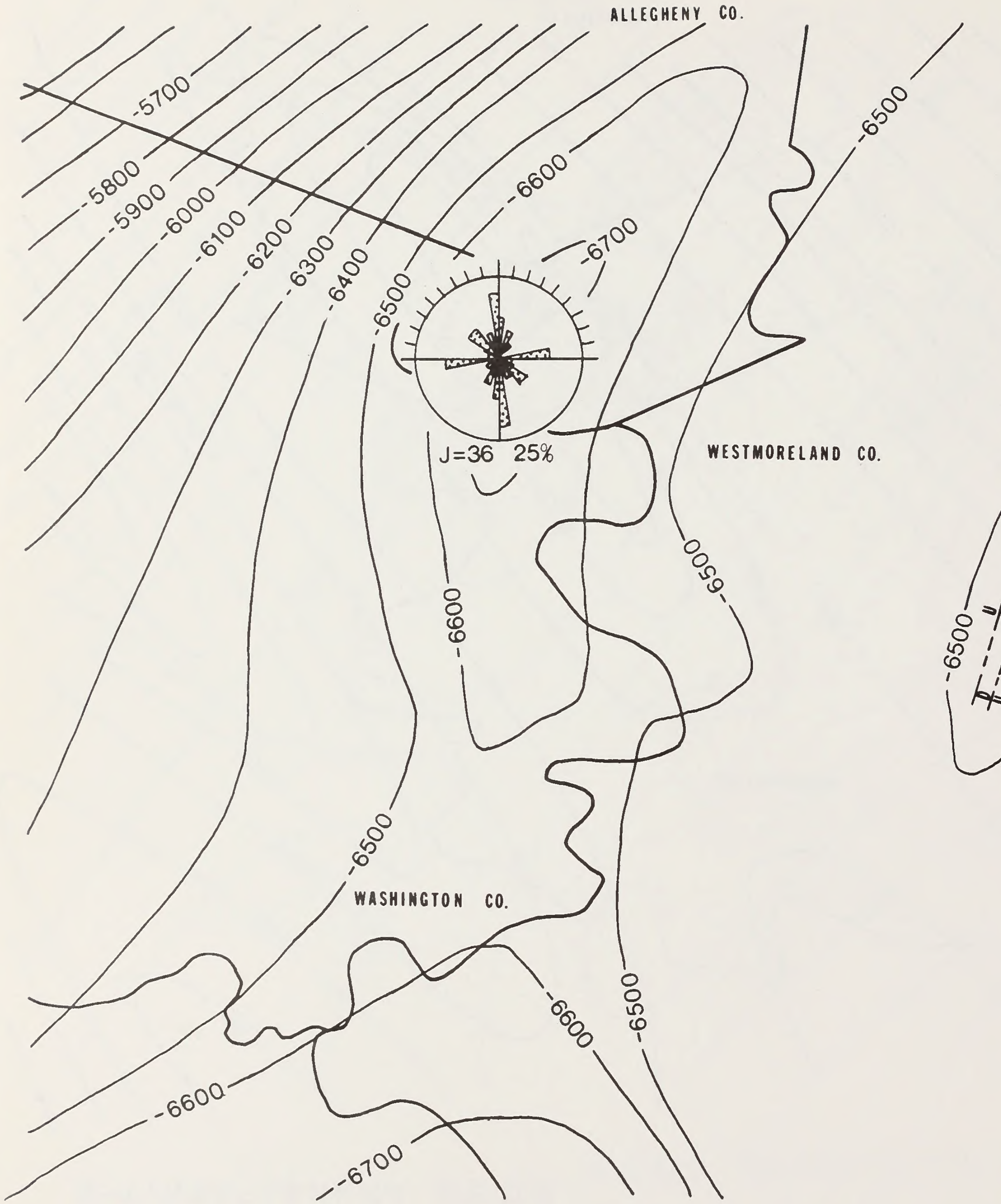
STRUCTURAL CONTOURS

TOP OF TULLY

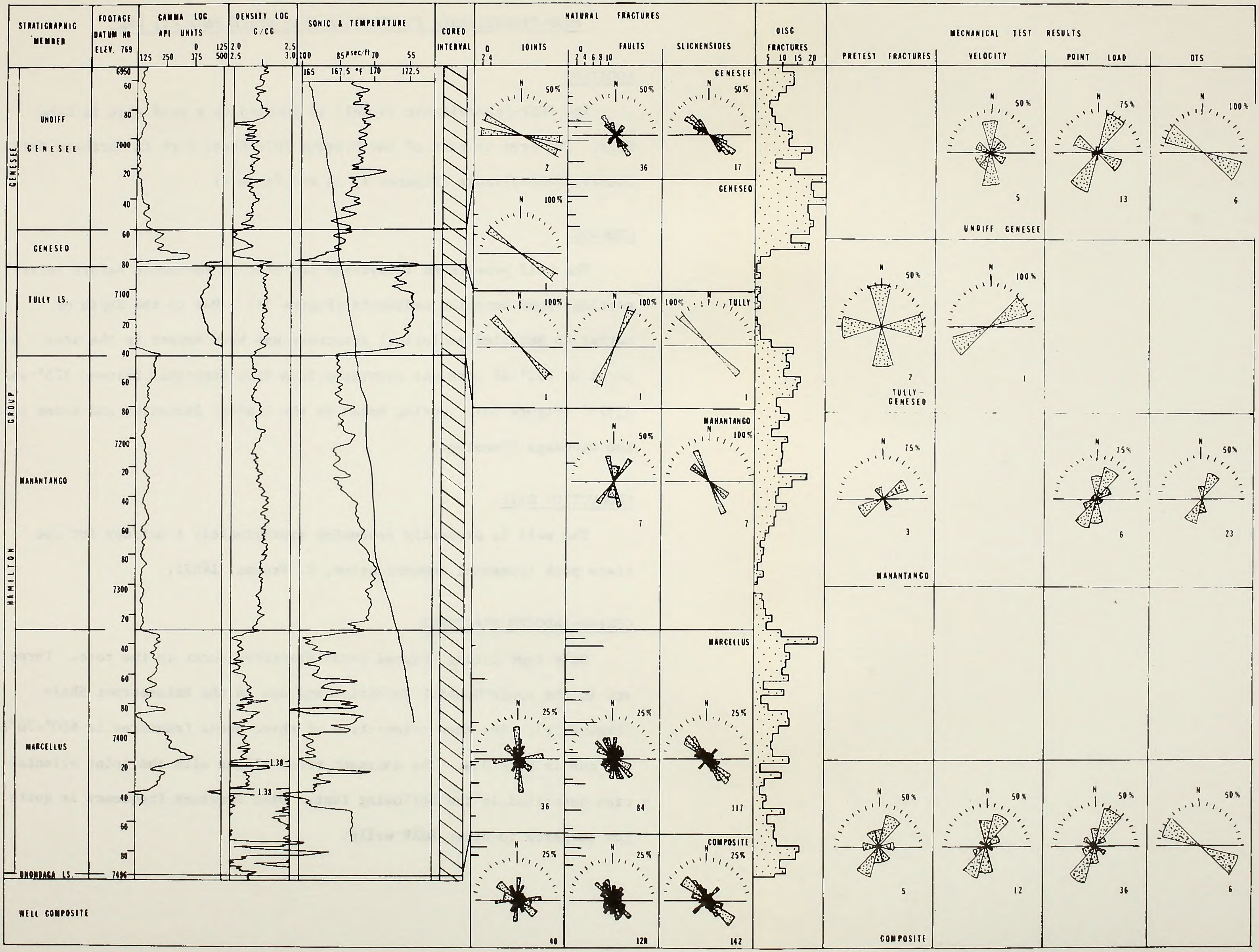
SCALE 1:250,000

FIGURE 2D

ROSE DIAGRAM: TULLY



E.G.S.P. PENNSYLVANIA-2
STRUCTURAL CONTOURS
TOP OF ONONDAGA
SCALE 1:250,000
FIGURE 2E
ROSE DIAGRAM: MARCELLUS



"D": DISTRIBUTION OF FRACTURES

FIGURE 2F E.G.S.P. PENNSYLVANIA 2 WELL SUMMARY

CLIFFS MINERALS, INC

EGSP-PENNSYLVANIA #3 (PRESQUE ISLE STATE PARK #1) WELL

LOCATION

The EGSP-Pennsylvania #3 well is located on a sand spit in Lake Erie. The area is part of the Presque Isle State Park in northern Erie County, Pennsylvania (Figures 1, 3A and Table 1).

GEOLOGY

The well penetrated lacustrine and glacial sediments before intersecting Upper Devonian sediments (Figure 3A). Due to the depth of burial no detailed geological structure has been mapped in the area. A total of 422' of core was recovered from five intervals between 375' and 1,275' (Figure 3D). Coring began in the Dunkirk Formation and ended in the Onondaga Limestone.

PRODUCTION DATA

The well is presently producing approximately 1 mcf/day for the state park (personal communication, K. Frohne, 1982).

CORING-INDUCED FRACTURES

Only four coring induced petal fractures occur in the core. Three are in the upper Dunkirk Formation and one in the Rhinestreet Shale (Figure 3D). The mean orientation of three petal fractures is N60°-70°E and one is N0°-10°W. The dominant trend aligns with the joint orientation described in the following text. Disc fracture frequency is quite low compared to other EGSP wells.

NATURAL FRACTURES

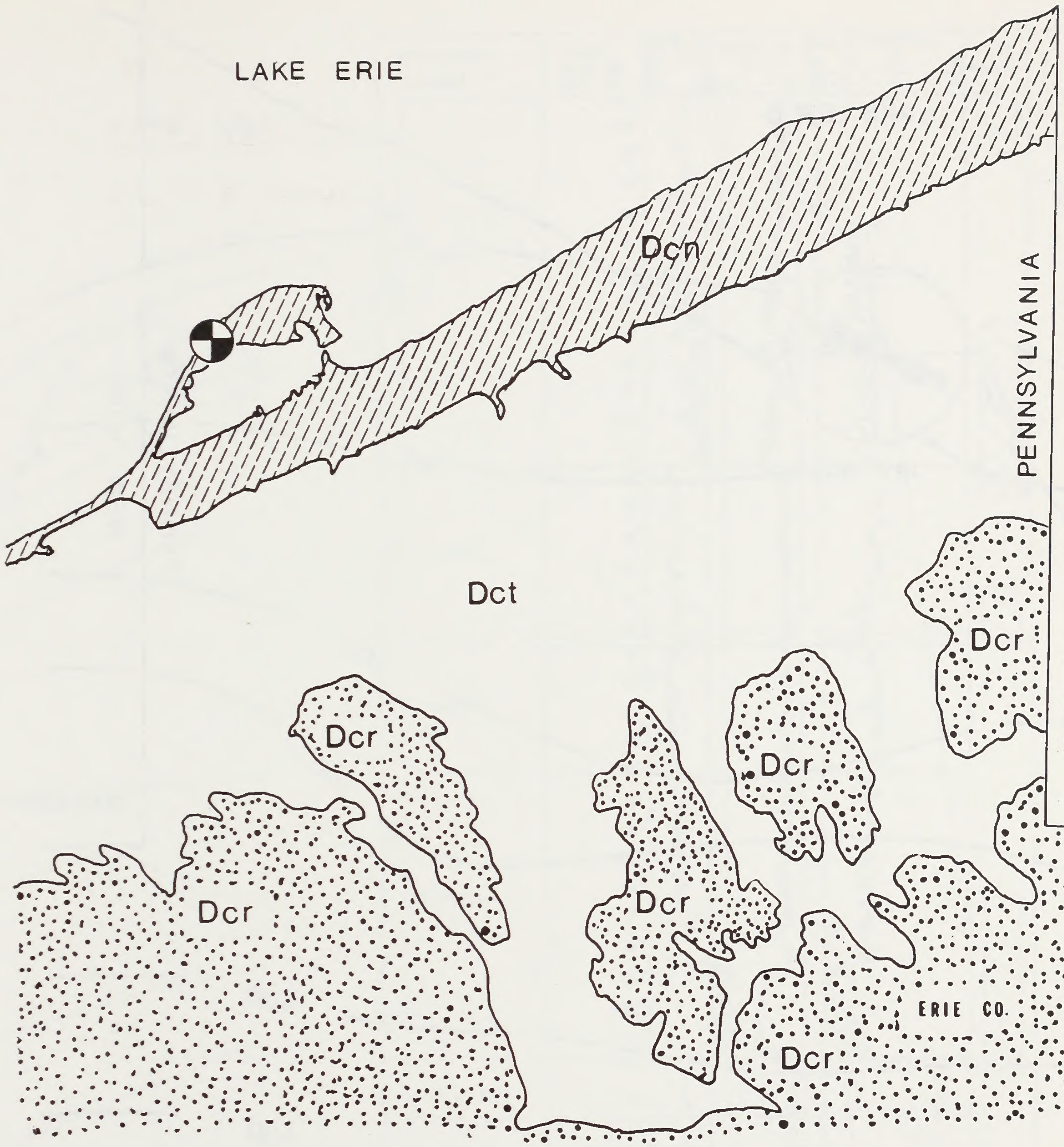
Ten joints occur in the two cored intervals of the Dunkirk Member with the strikes varying from N50°E to N80°E. The four joints in the upper cored interval were not oriented as they occur in the pressure cored sample from 385' to 395'. One of these joints has barite and calcite mineralization. The remaining seven joints are in the second cored interval and strike NE (Figure 3D). None of the fractures exceeded one foot in length and all occur in silty mudstone. The four microfaults in the lower Dunkirk Member display a variety of strikes due to their occurrence in shales above and below a calcareous siltstone. The faults under the siltstone have calcite mineralization. The shales contain pyritized burrows and pyrite nodules whose presence lead to development of variable strikes and dips on the associated fault planes. Two trends of fault movement were defined. The first is N20°-30°W which is normal to the joint system in the Dunkirk Member. The second is N40°-60°E, almost parallel to the joint trend.

The fracture system in the Dunkirk suggests that the tectonic stresses associated with the Allegheny Orogeny did affect the Devonian sediments in this area some 130 miles NW of the Allegheny Front of the Appalachian Mountains. The faulting shows movement parallel to the maximum horizontal stress projected during the Allegheny Orogeny with the lesser movement direction the result of the shales sliding normal to maximum horizontal stress to fill in the void created by extension of the sediments. The joint trend may be the result of the relaxation of the maximum horizontal stress or development of a horizontal compressive stress system parallel to the N60°-70°E trend. The alignment of the

coring induced fractures suggests that a present day maximum horizontal stress is developed in the N60°-70°E direction.

MECHANICAL TEST RESULTS

Pretest fractures show an E-W maximum in the well composite with a secondary N60°E trend. The velocity trend at N60°W is opposed to the pretest fracture trend. Point load tests and DTS tests show random orientations on the well composites (Figure 3D). The conclusion is that the rocks have not been exposed to a stress strong enough to develop a fabric this far from the Allegheny Front.



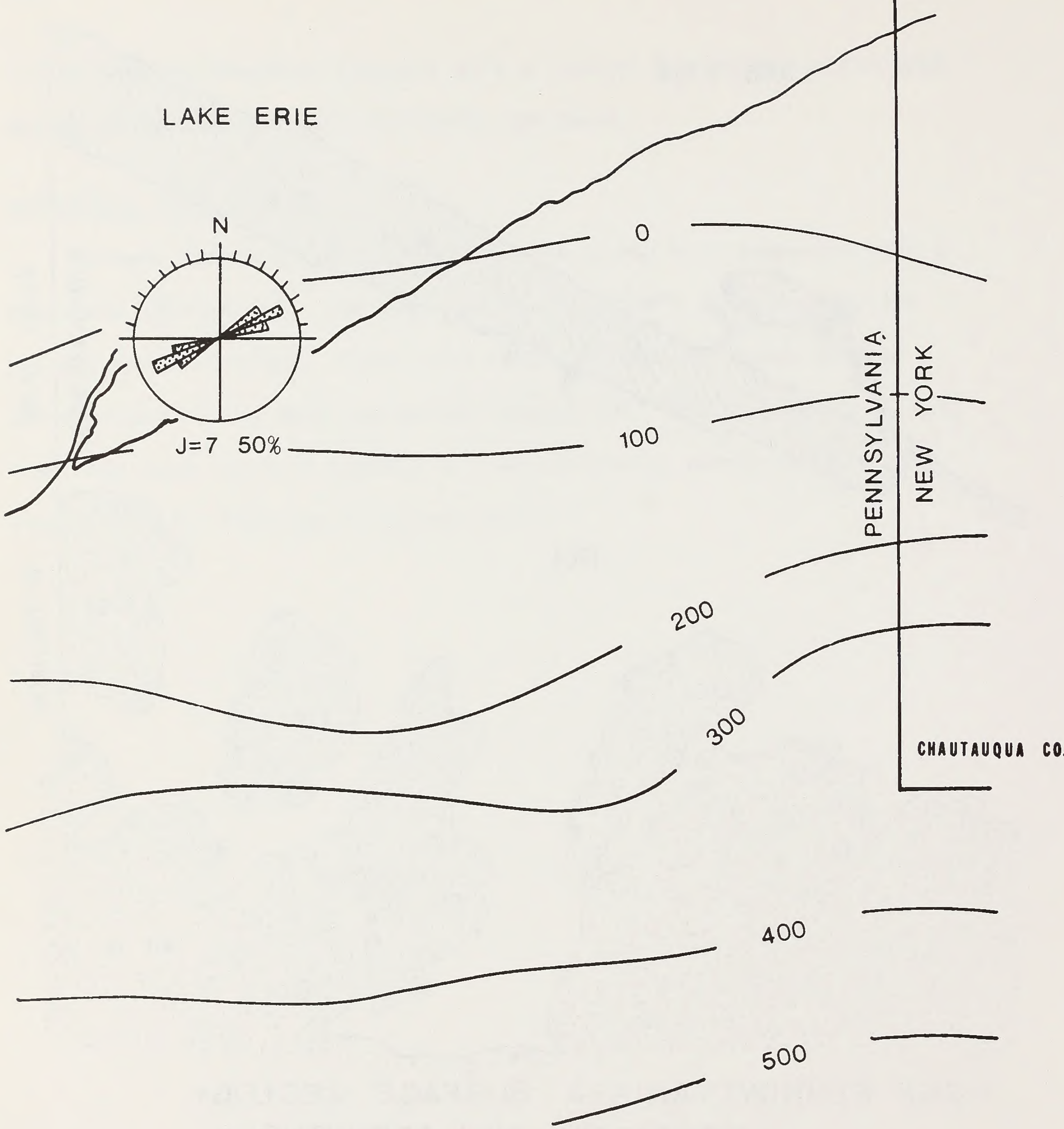
E.G.S.P. PENNSYLVANIA-3 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

Dcr	CATTARAUGUS Fm.	Devonian
Dct	CONNEAUT Fm.	
Dcn	CANADAWAY Fm.	

SCALE 1 : 250,000

FIGURE 3A



E.G.S.P. PENNSYLVANIA-3

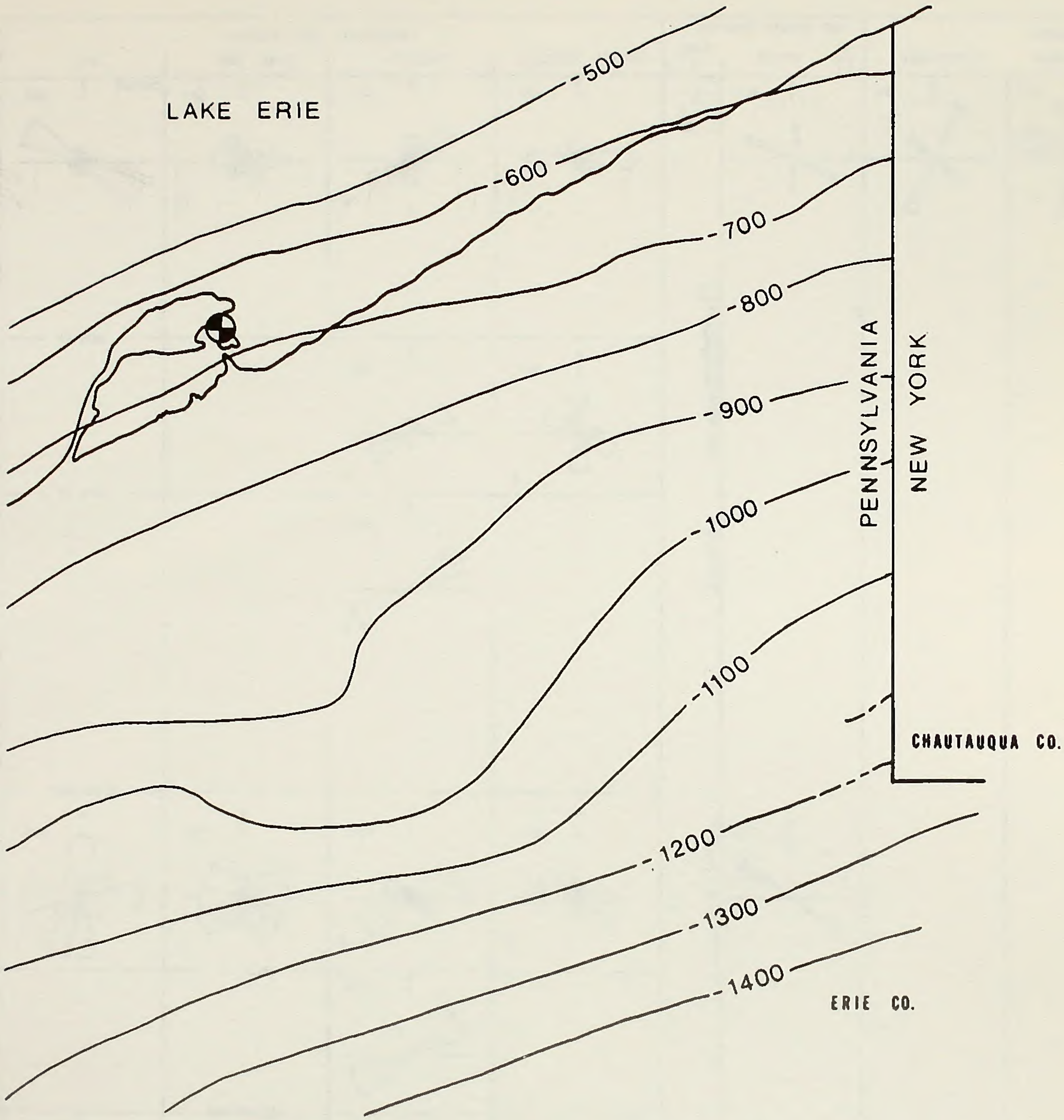
STRUCTURAL CONTOURS

BASE OF DUNKIRK

SCALE 1:250,000

FIGURE 3B

ROSE DIAGRAM: DUNKIRK



E.G.S.P. PENNSYLVANIA-3

STRUCTURAL CONTOURS

TOP OF ONONDAGA

SCALE 1:250,000

FIGURE 3C

ROSE DIAGRAM: ONONDAGA

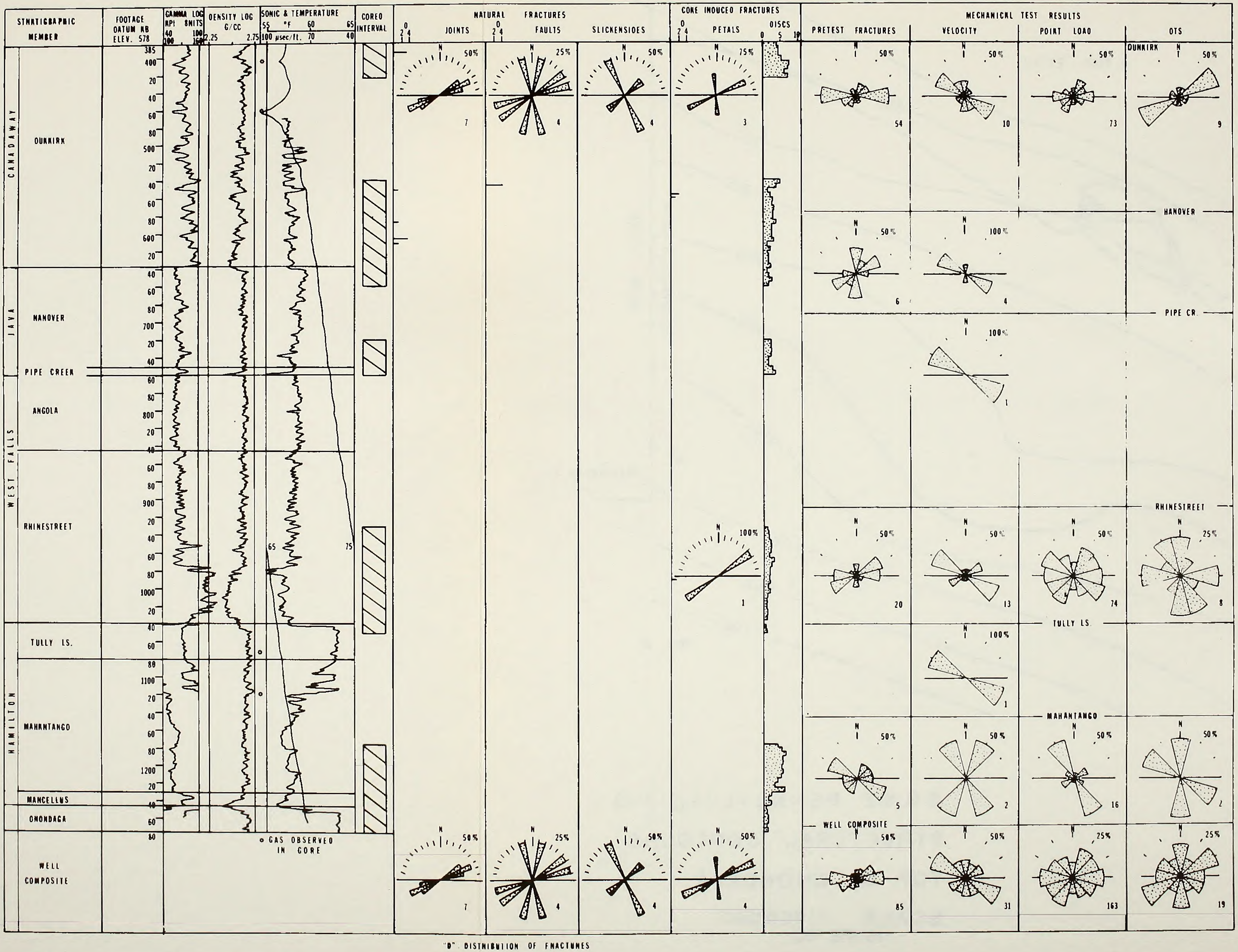


FIGURE 3D E.G.S.P. PENNSYLVANIA 3 WELL SUMMARY

CLIFFS MINERALS, INC

EGSP-PENNSYLVANIA #4 (GLENN McCALL #5) WELL

LOCATION

The EGSP-Pennsylvania #4 well is located three miles southwest of the city of Indiana, Indiana County, Pennsylvania (Figures 1, 4A and Table 1).

GEOLOGY

The well site is on the west flank of the Chestnut Ridge Anticline and is bounded on the north and south by cross-strike discontinuities that offset the trend of the anticline axes (Figure 4A). The discontinuity north of the well site also has ultramafic dikes associated with it that strike NE to N80°E and intrude the Pennsylvanian Conemaugh sediments of the area. The structure maps of the Devonian sediments show the prominent Chestnut Ridge Anticline to the east and a parallel synclinal structure to the west (Figure 4B - 4G). The Onondaga structural detail was projected from the Oriskany Sandstone immediately below and from which better well control data is available (Cate, 1962). The detail indicates a more complex fault structure associated with the anticlines at depth and projects higher fracture porosity in the overlying organic shales. Faulting occurs as reverse faults parallel to anticline axes creating graben structures in limestones in the core of the anticline. Transverse faults have also been mapped by Cate and Gwinn on their detailed structure maps of the area.

Coring began at 7,098' in the Cashaqua Member of the Sonyea Formation and ended at approximately 8,009' in the Marcellus Member of the

Hamilton Group. Difficulties with coring caused the loss of the lower 150' of the well and unoriented core (Figure 4J). As coring approached 8,000' problems were encountered with excessive heat, causing the plastic core barrel liner to soften and collapse. This caused jamming in the core barrel and some rubblization of core. When coring was attempted below 8,012', the core barrel jammed in the well. After the barrel was freed coring was attempted a second time, but the barrel jammed in the hole again and could not be recovered. The core orientation equipment which attaches to the top of the inner core barrel was also lost. The remainder of the drill string was retrieved and coring attempts were discontinued. Approximately 30' of core had been lost or rubblized from 7,900' to the end of coring in addition to the core left in the barrel.

CORING-INDUCED FRACTURES

No petal fractures appeared in the core. The majority of induced fractures are the disc type whose frequency of occurrence is from five to 20 per foot. This frequency is low when compared to the other deep wells in the Appalachian Basin.

NATURAL FRACTURES

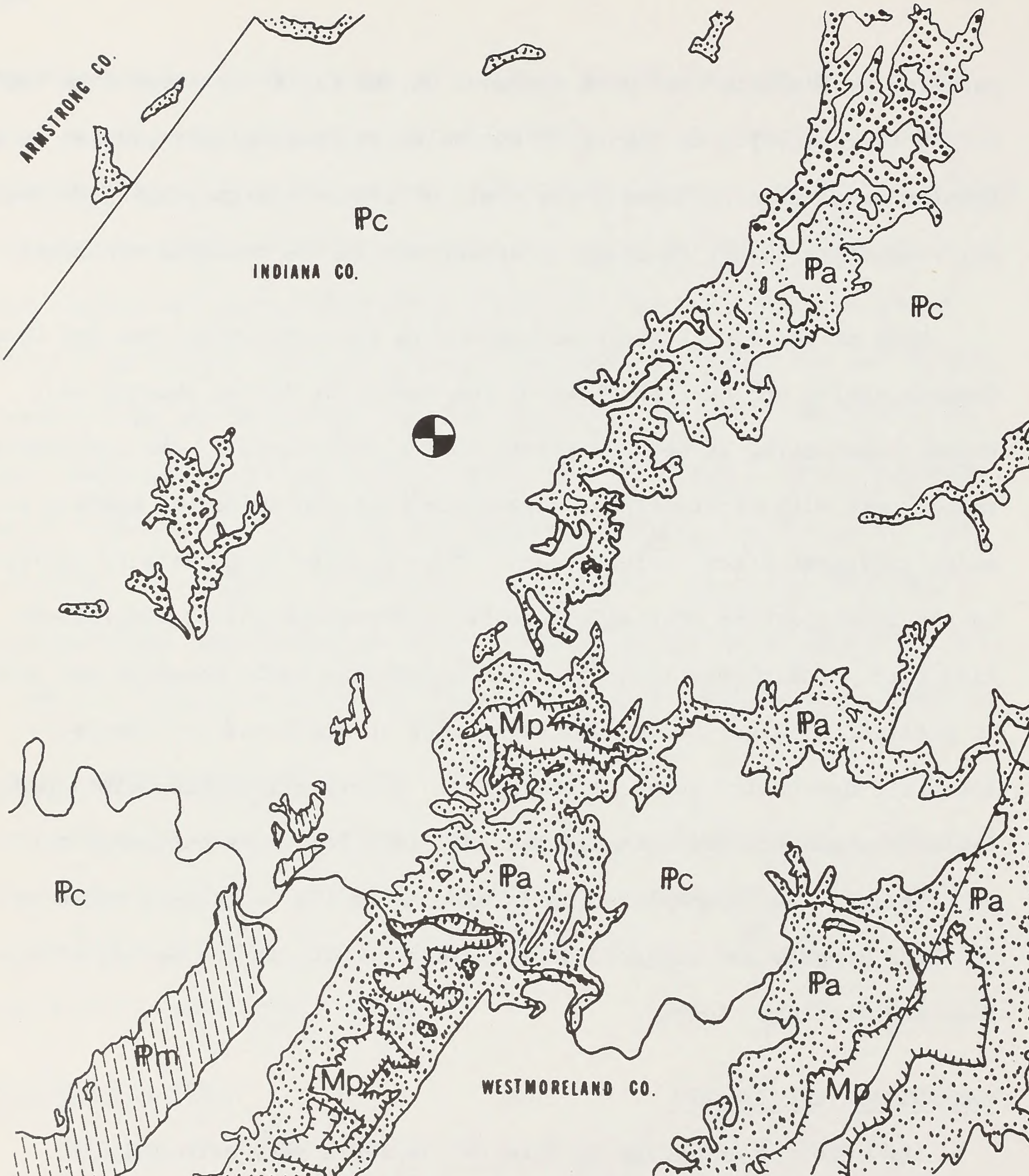
The composite rose diagram of joint orientations shows a very strong N50°-60°W trend (Figure 4J). The trend is consistent throughout the stratigraphic section with a slight scatter of orientations in the Middlesex and Genesee Shales. Joint alignment is normal to the fold axes; jointing is the direct result of horizontal compressive stresses developed during the Allegheny Orogeny. Strikes on the fault planes are

parallel to the fold axes with movement on the faults oriented from N50°W to E-W (Figure 4J). In Figure 4H the poles to fault planes plotted on a Schmidt equal area net show a low angle of dip on faults dipping NW and SE, suggesting thrust faulting or detachment in the Devonian sediments.

Most of the faults are concentrated in the Lower Middlesex and Upper Genesee Shales and near the base of the Marcellus Shale, showing that these shales acted as bedding planes during deformation. The slickenside trends vary with stratigraphy, suggesting that the different members were under different stress orientations. This feature is especially noticeable in the upper portion of the Genesee Shale where the joint orientations also vary. The change in joint orientations and fault movement may also be related to larger geological structures at depth and to behavior of the shale due to its physical character. Nearly all of the joints and faults are mineralized with calcite and, to a lesser extent, with pyrite or dolomite. The mineralization is similar to the other deep wells in the EGSP program and suggests high fluid pressures in the shales at the time the fractures formed.

MECHANICAL TEST RESULTS

The velocity and point load tests display a very strong N30°E orientation of weakness planes in the core. Variability in pretest fractures and DTS tests are likely the result of both coring difficulties and inherent fissility of the shales encountered. The N30°E anisotropy is parallel to the major folding and is a direct result of stresses created during the Allegheny Orogeny.



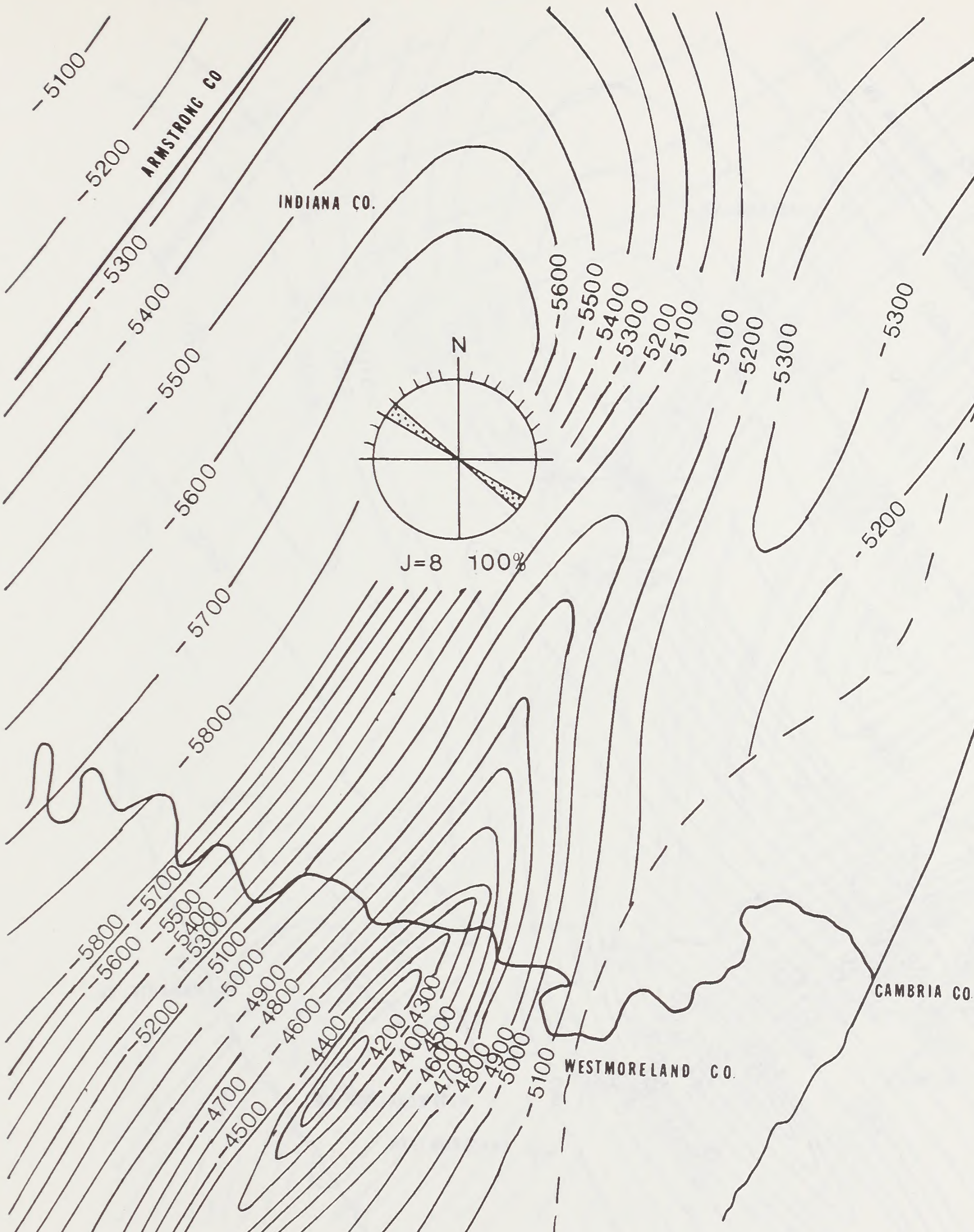
E.G.S.P. PENNSYLVANIA-4 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

ℙm	MONONGAHELA Fm.	
ℙc	CONEMAUGH Fm.	Pennsylvanian
ℙa	ALLEGHENY Gp.	
Mp	POCONO Gp.	Mississippian

SCALE 1 : 250,000

FIGURE 4A

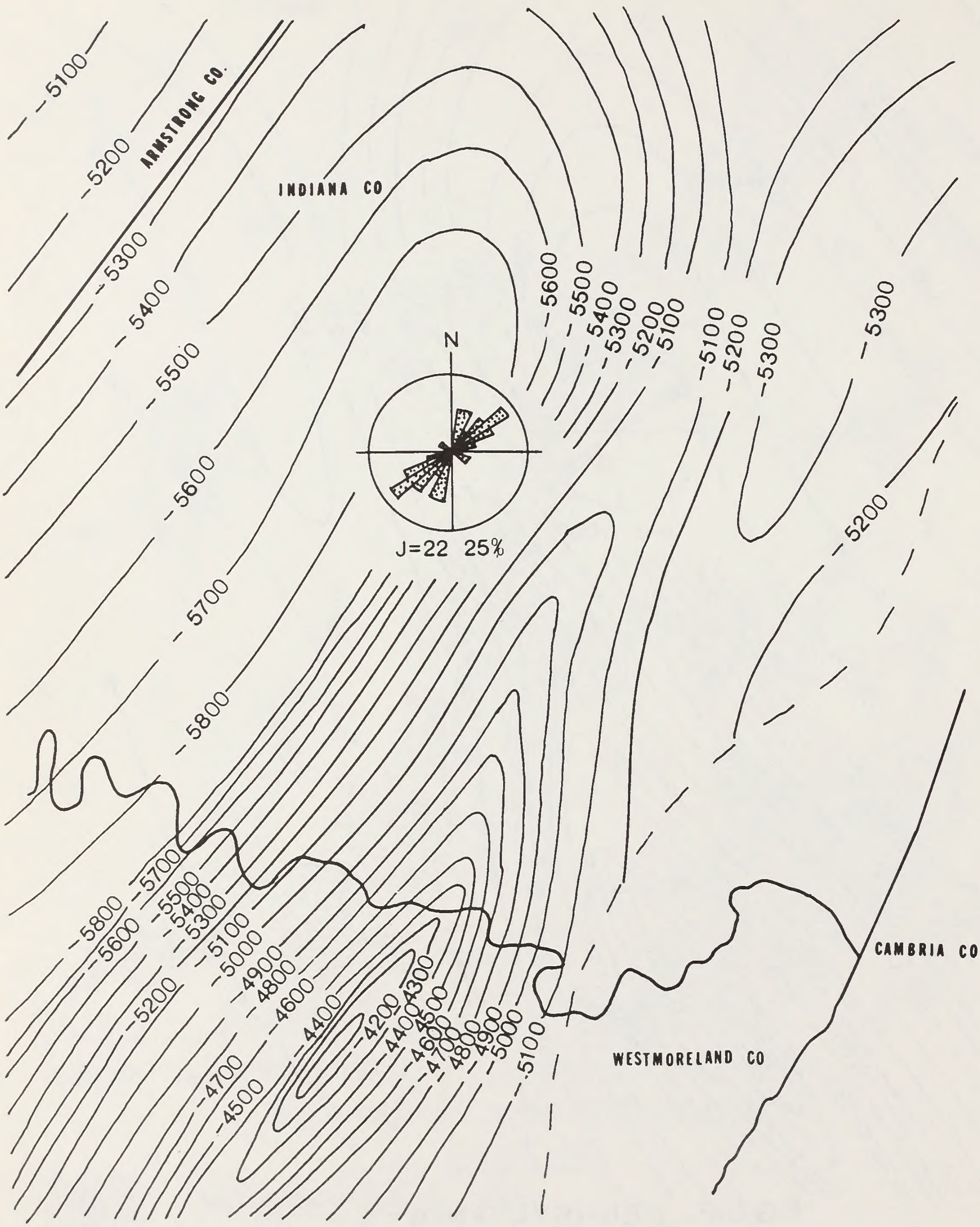


E.G.S.P. PENNSYLVANIA - 4
STRUCTURAL CONTOURS
TOP OF MIDDLESEX

SCALE 1 : 250,000

ROSE DIAGRAM : CASHAQUA

FIGURE 4B

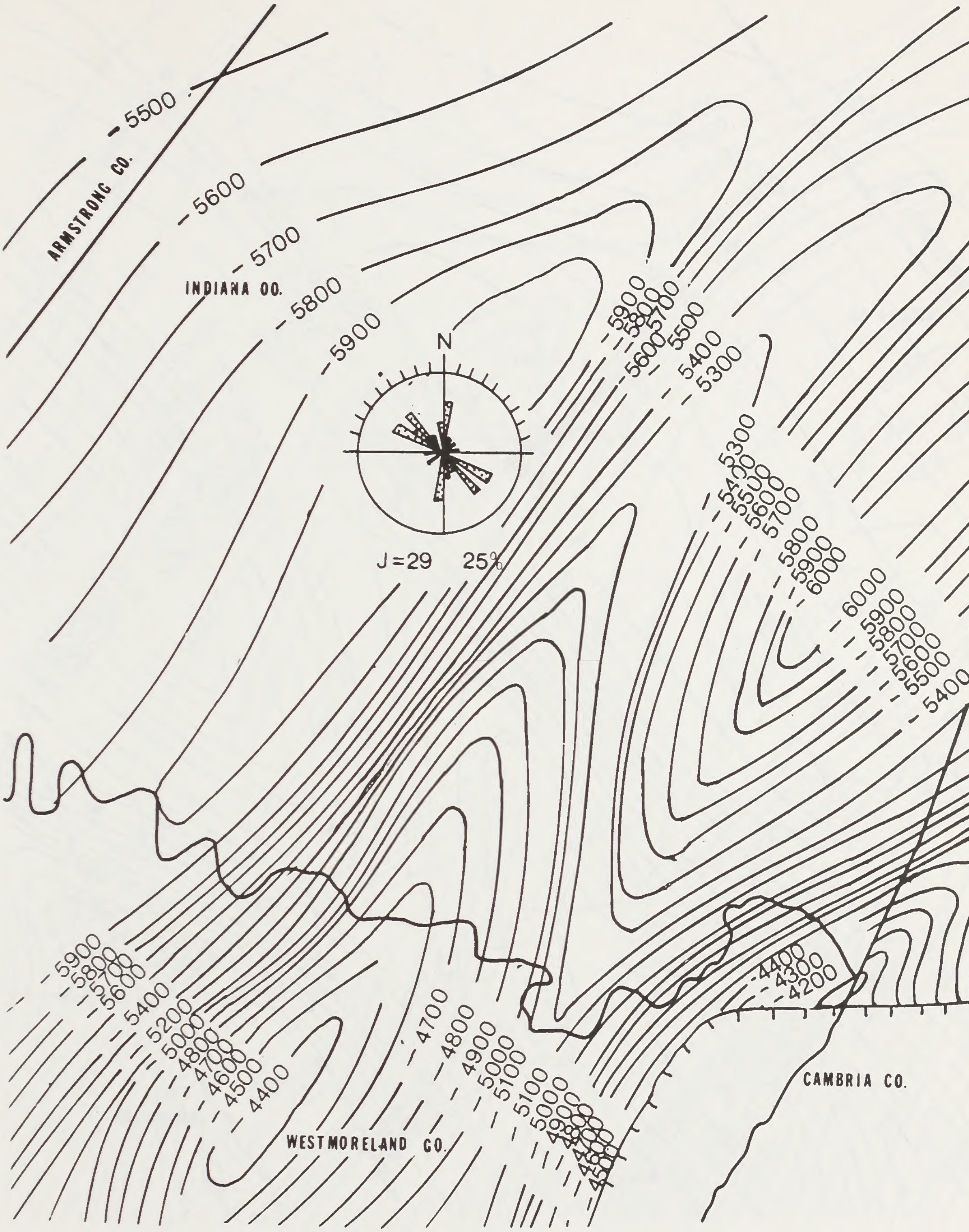


E.G.S.P. PENNSYLVANIA-4
STRUCTURAL CONTOURS
TOP OF MIDDLESEX

SCALE 1 : 250,000

ROSE DIAGRAM MIDDLESEX

FIGURE 4C

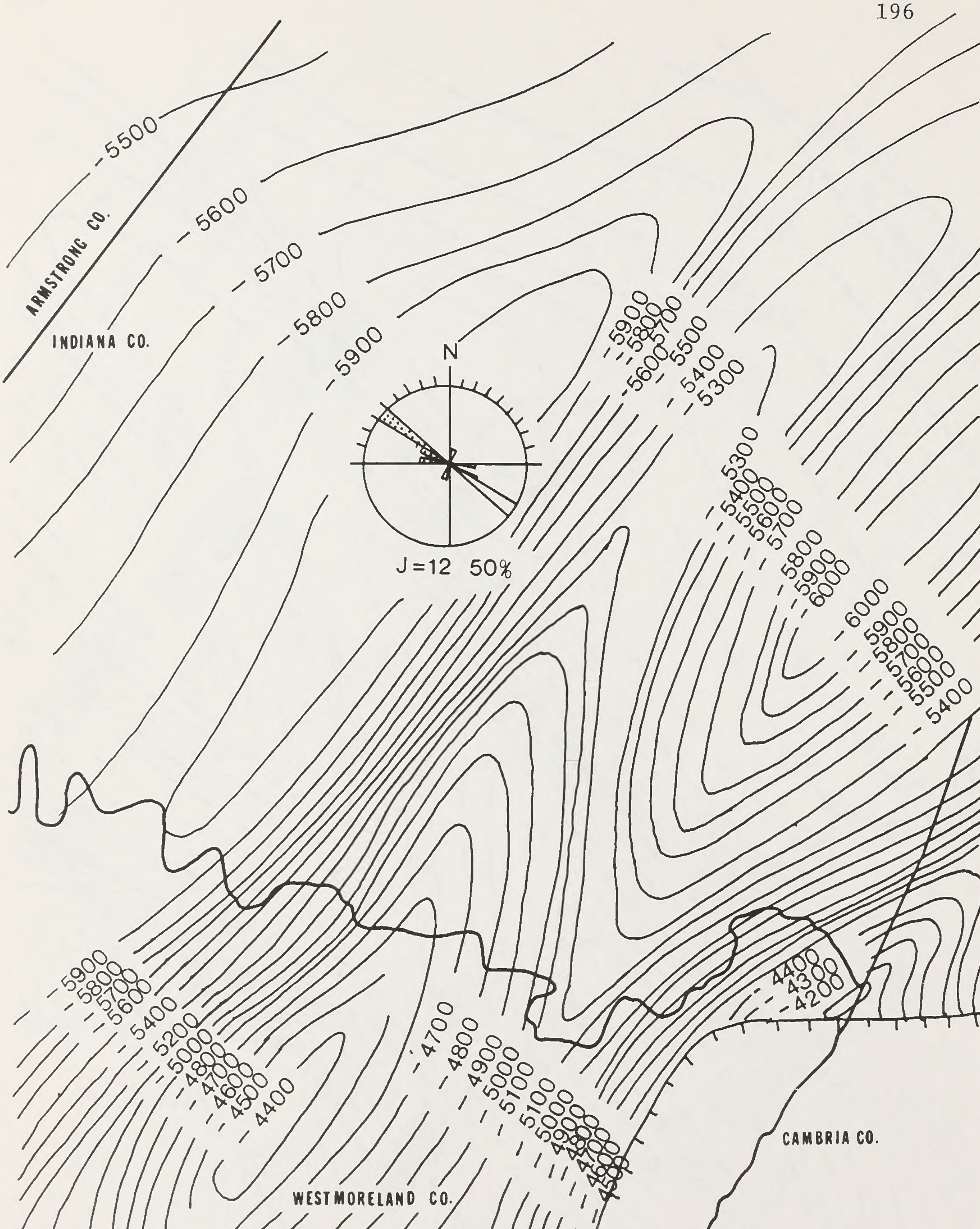


E.G.S.P. PENNSYLVANIA-4
STRUCTURAL CONTOURS
TOP OF TULLY

SCALE 1 : 250,000

ROSE DIAGRAM : GENESEE UNDIF.

FIGURE 4D

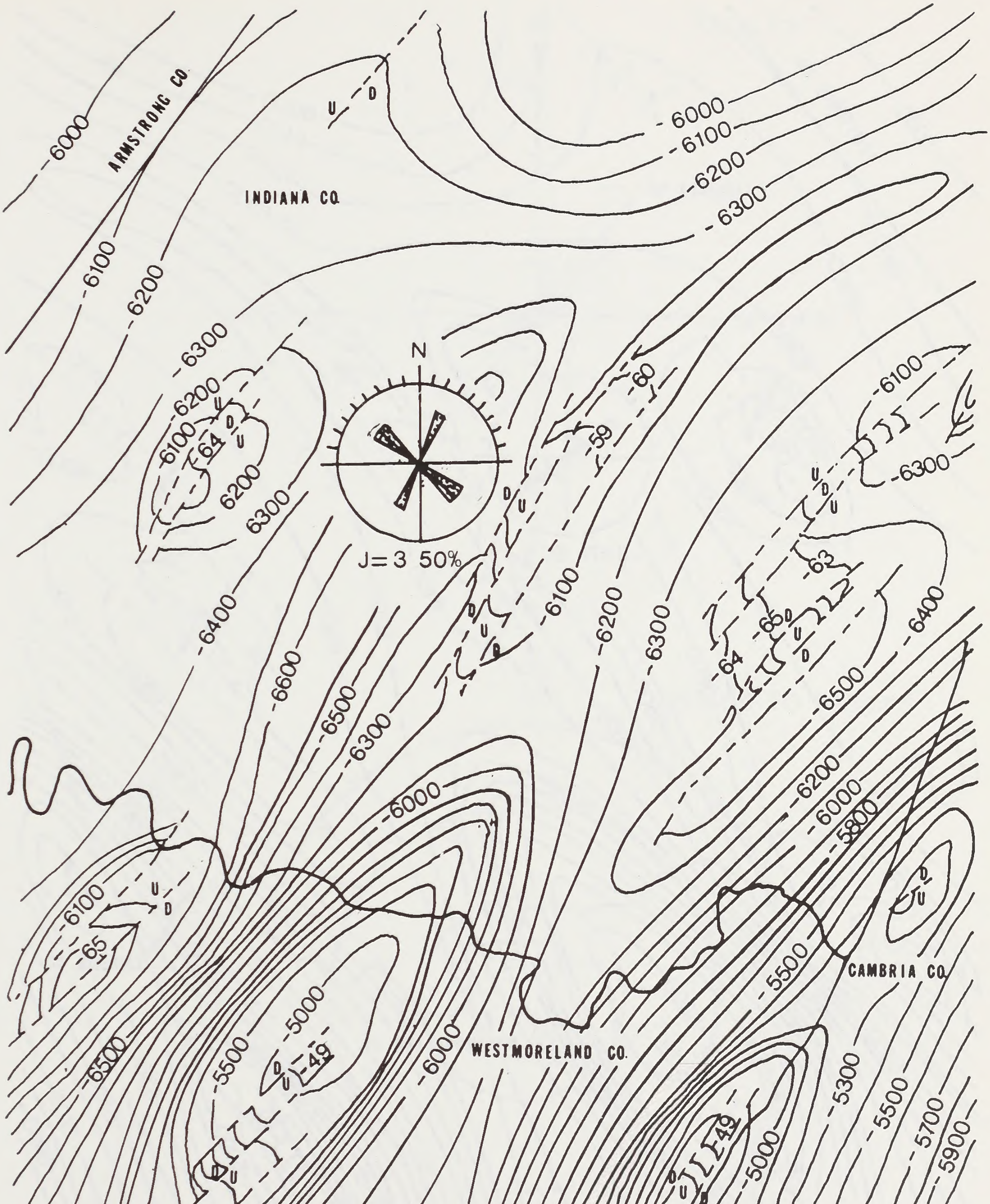


E.G.S.P. PENNSYLVANIA-4
STRUCTURAL CONTOURS
TOP OF TULLY

SCALE 1:250,000

ROSE DIAGRAM : GENESEO

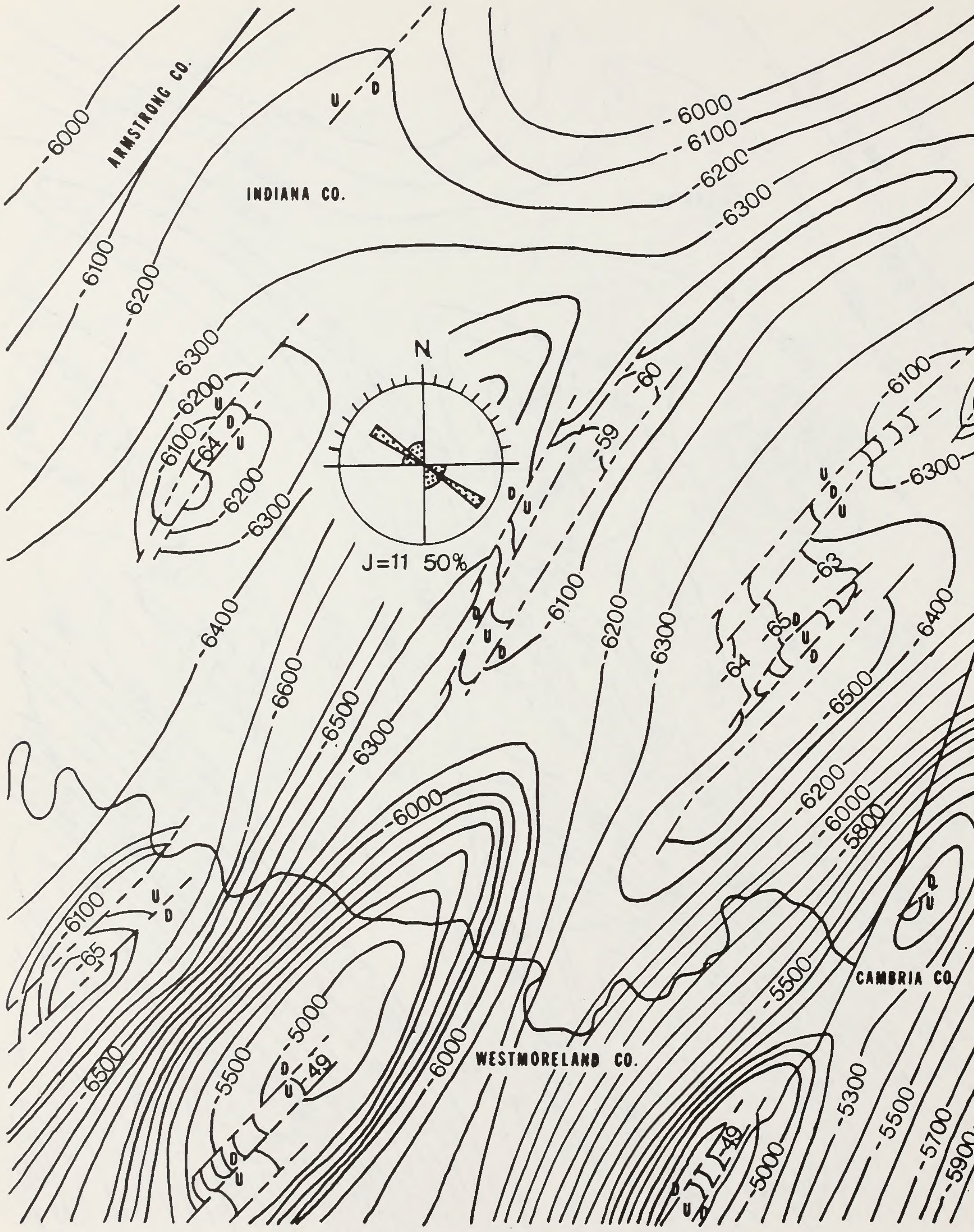
FIGURE 4E



E.G.S.P. PENNSYLVANIA-4
STRUCTURAL CONTOURS
TOP OF ONONDAGA

SCALE 1 : 250,000

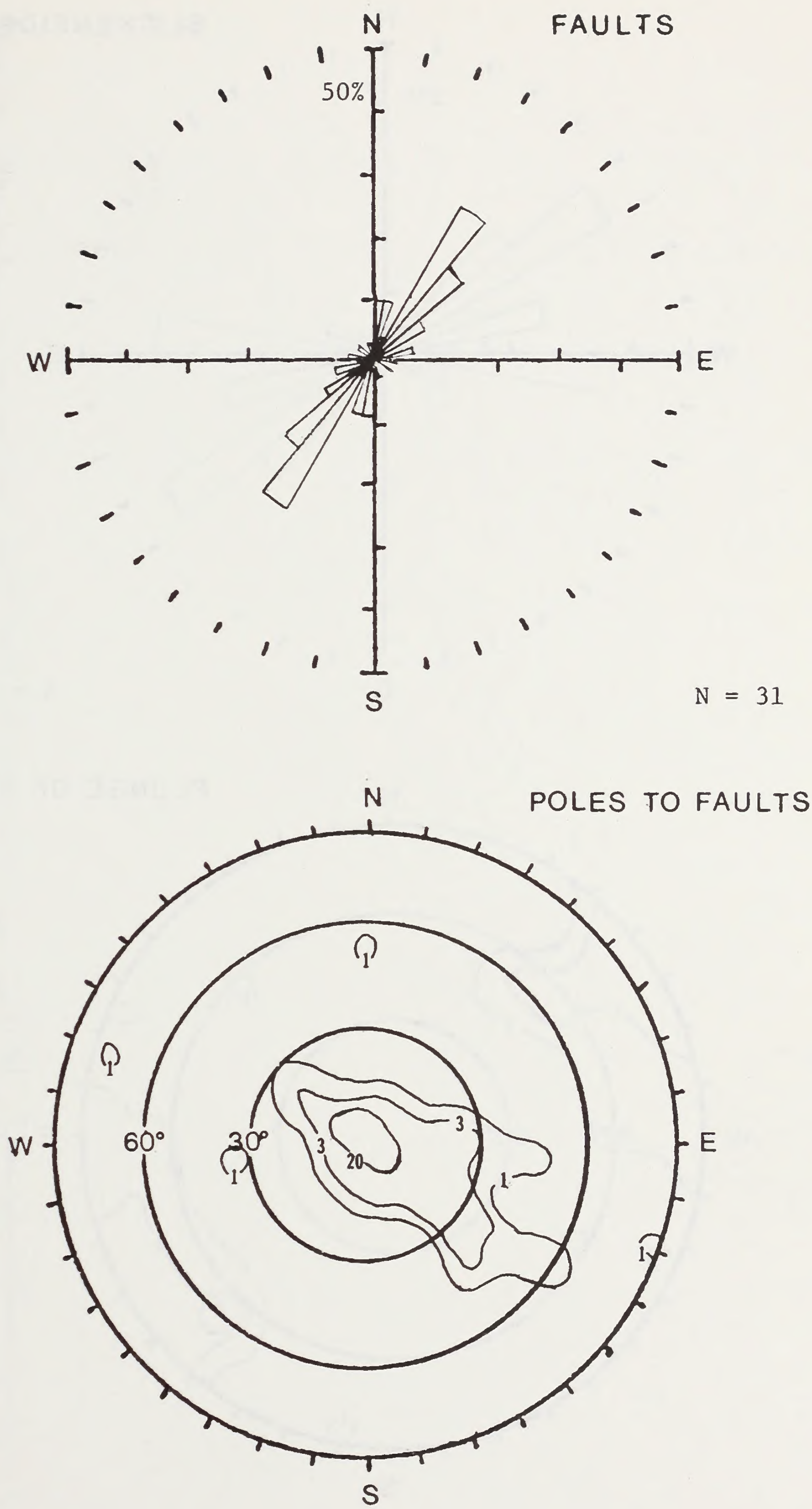
ROSE DIAGRAM : MAHANTANGO
FIGURE 4F



E.G.S.P. PENNSYLVANIA-4
STRUCTURAL CONTOURS
TOP OF ONONDAGA

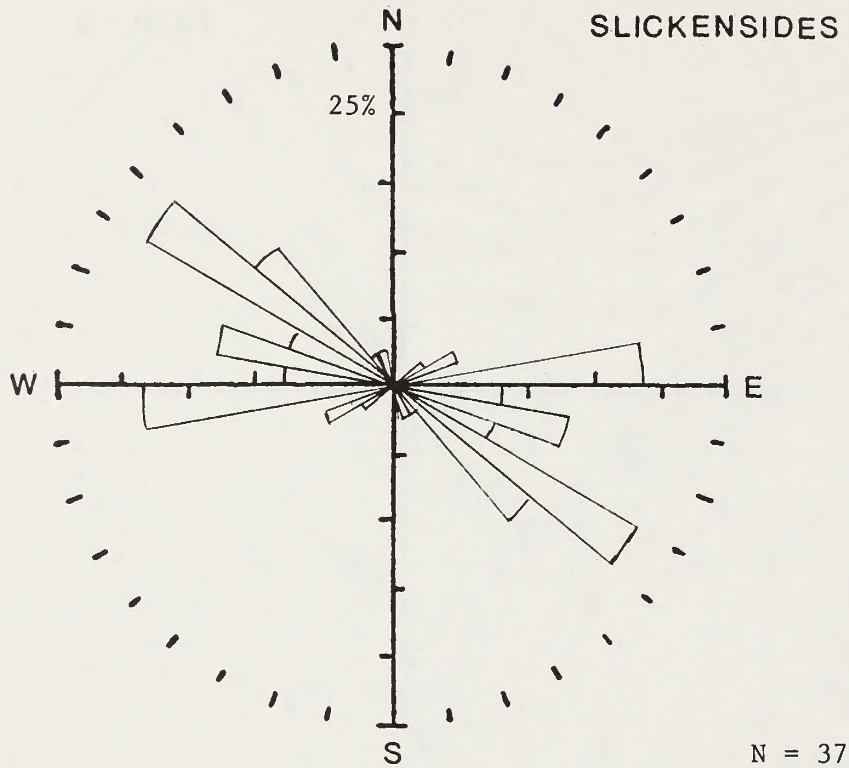
SCALE 1:250,000

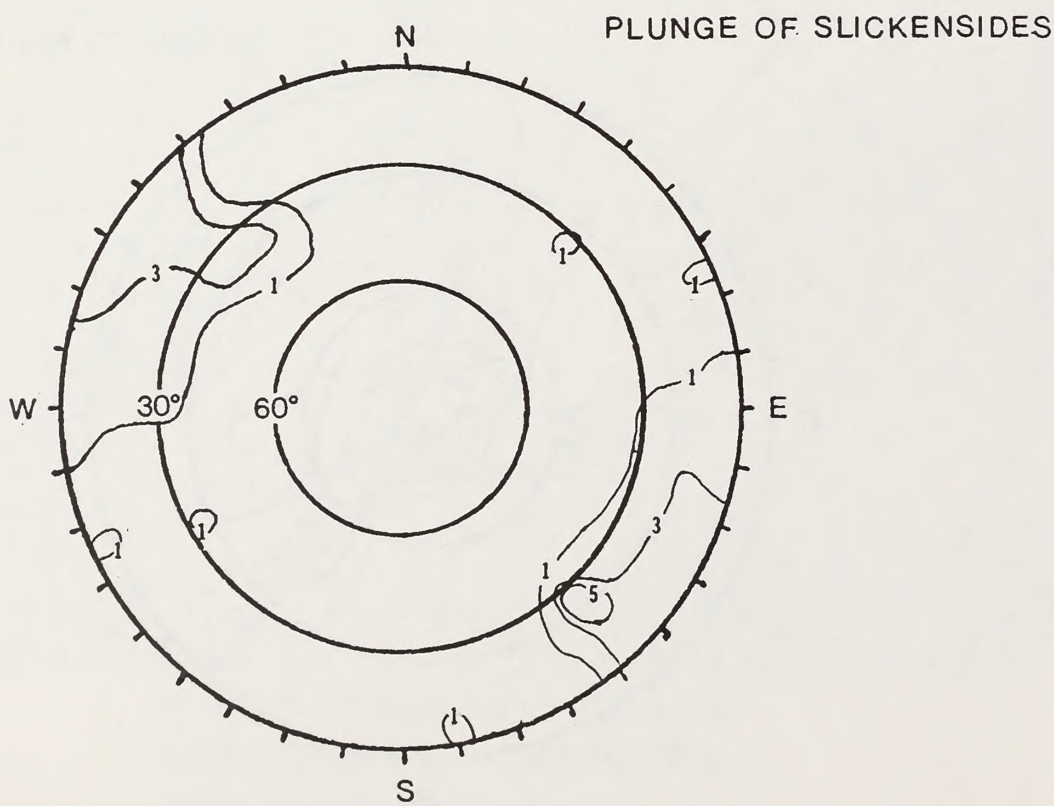
ROSE DIAGRAM : MARCELLUS
FIGURE 4G



EGSP-PENNSYLVANIA #4

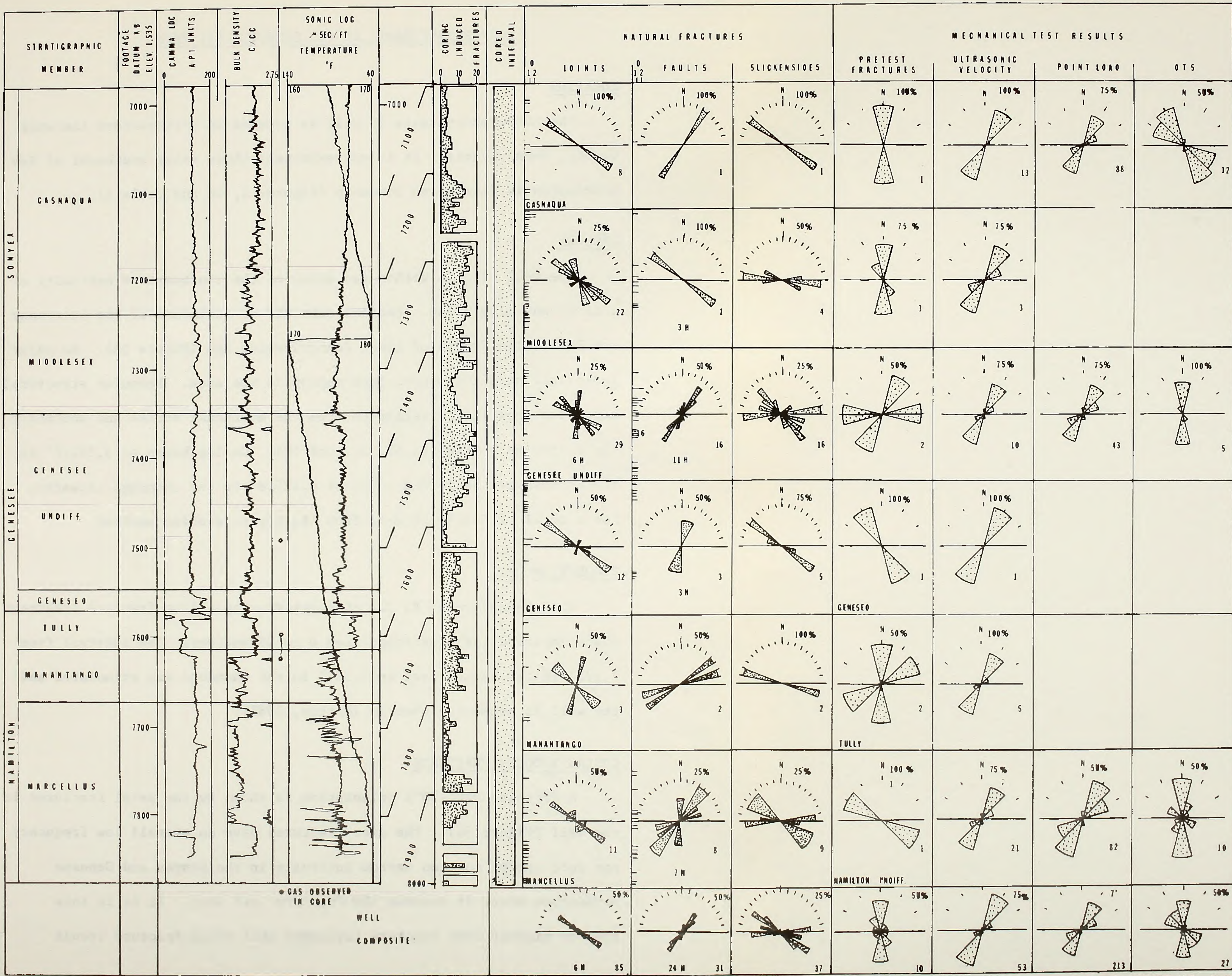
Figure 4H. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.





EGSP-PENNSYLVANIA #4

Figure 4I. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.



"N" DISTRIBUTION OF FRACTURES
"H" HORIZONTAL

FIGURE 41 EGSP PENNSYLVANIA 4 WELL SUMMARY

CLIFFS MINERALS, INC.

EGSP-PENNSYLVANIA #5 (C. SOKEVITZ #1) WELL

LOCATION

The EGSP-Pennsylvania #5 well is located in northeastern Lawrence County, Pennsylvania. It is approximately three miles southeast of New Wilmington in Wilmington Township (Figures 1, 5A and Table 1).

GEOLOGY

The well site is within ten miles of the southeastern extremity of most recent glaciation. Bedrock consists of sediments of the Allegheny and Pottsville Groups of Lower Pennsylvanian Age (Figure 5A). No major geological structures have been mapped in the area. Devonian structural maps also show little variation from the northeast strike and southeast dip of the beds (Figures 5B, 5C, and 5D). Coring began at 3,522.0' in the Rhinestreet Shale and ended at 4,125.8' in the Onondaga Limestone for a total of 603.8' of core from the Upper Devonian section.

PRODUCTION DATA

EGSP-Pennsylvania #5 was stimulated using a foam fracture treatment which improved gas production from 0 to 28 mcf/day. The interval from 3,678' in the Rhinestreet to 4,125' in the Onondaga was stimulated and the well is presently shut in (Horton, 1981).

CORING-INDUCED FRACTURES

A definite N40°-50°E orientation is shown by the petal fractures in the well (Figure 5G). The disc fractures have an overall low frequency per foot except for two narrow intervals in the Sonyea and Genesee Formations where it exceeds 100 fractures per foot. It is in this area of highest disc fracture frequency that petal fracture trends

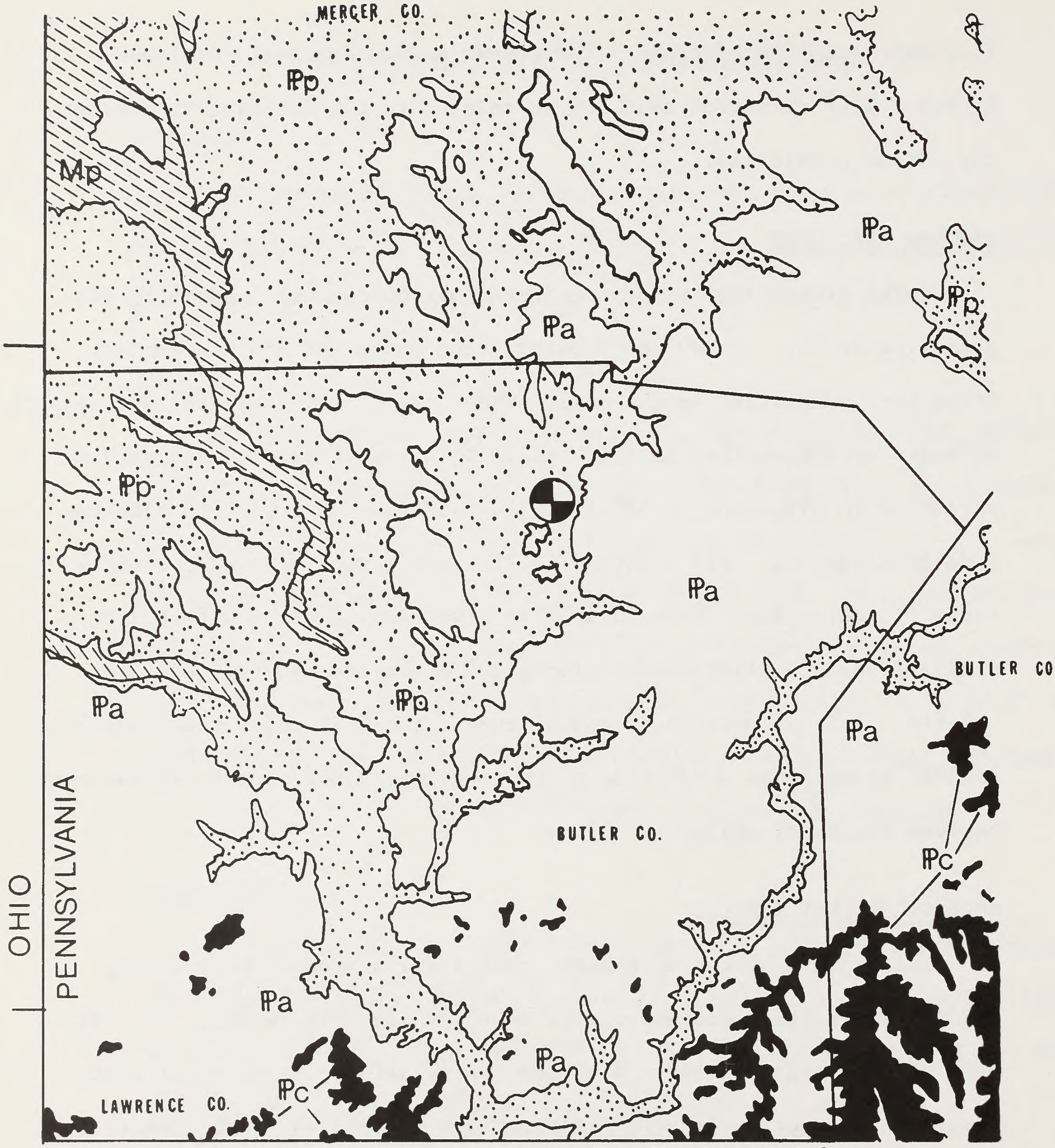
fluctuate from the NE trend. The trends indicate a well-developed stress relief direction that may be related to the faulting or present day stress conditions.

NATURAL FRACTURES

Joint trends indicate two orientations on the well composite diagram (Figure 5G). A N70°-80°W major trend and a N40°-50°W secondary trend were identified in the core. These trends may indicate two separate episodes of deformation in this area. This hypothesis is supported by variation in alignment of fault strikes and wide variation in slickenside orientations. All measured faults except two occur near concretions in the shales. Most notable is a vertical fault 0.4 feet long, striking N45°W. Slickensides plunge 20°NW and are mineralized with calcite. This occurrence is one of two in the EGSP wells that indicates visible movement on a vertical plane, suggesting horizontal displacement between blocks of shale.

MECHANICAL TEST RESULTS

The summary of the mechanical test results shows a very strong N30°E trend to the weakness planes in the shale (Figure 5G). The alignment of the petal fractures with the fabric defined by physical tests suggests that coring induced fractures are controlled by the fabric or by a stress that produced the NE trending slickensides on the faults. Tests show that a well-developed fabric is present and probably was formed by stresses created at the onset of the Allegheny Orogeny.



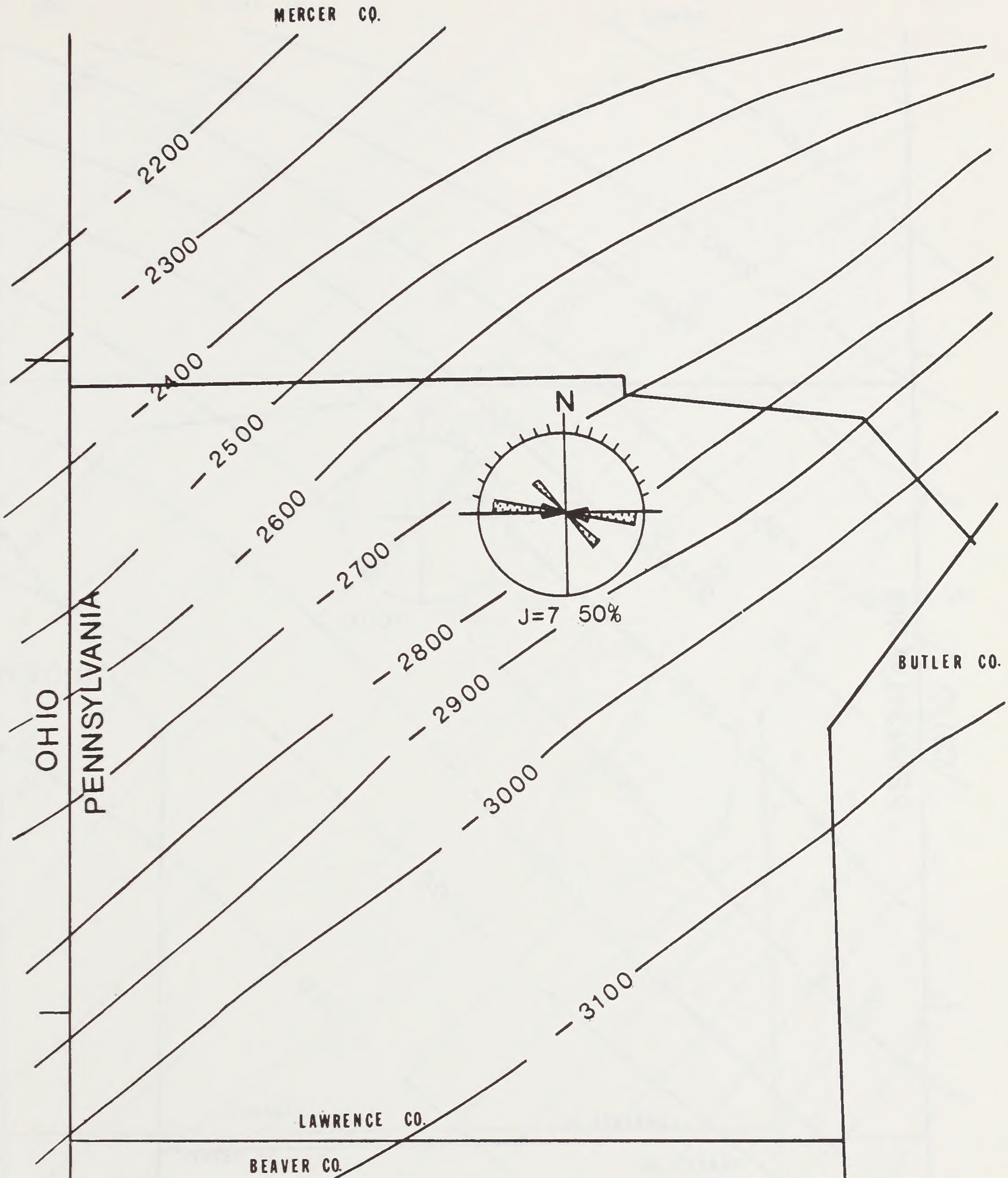
E.G.S.P. PENNSYLVANIA-5 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

Pc	CONEMAUGH Fm.	Pennsylvanian
Pa	ALLEGHENY Gp.	Pennsylvanian
Pp	POTTSVILLE Gp.	Pennsylvanian
Mp	POCONO Gp.	Mississippian

SCALE 1 : 250,000

FIGURE 5A



E.G.S.P. PENNSYLVANIA-5

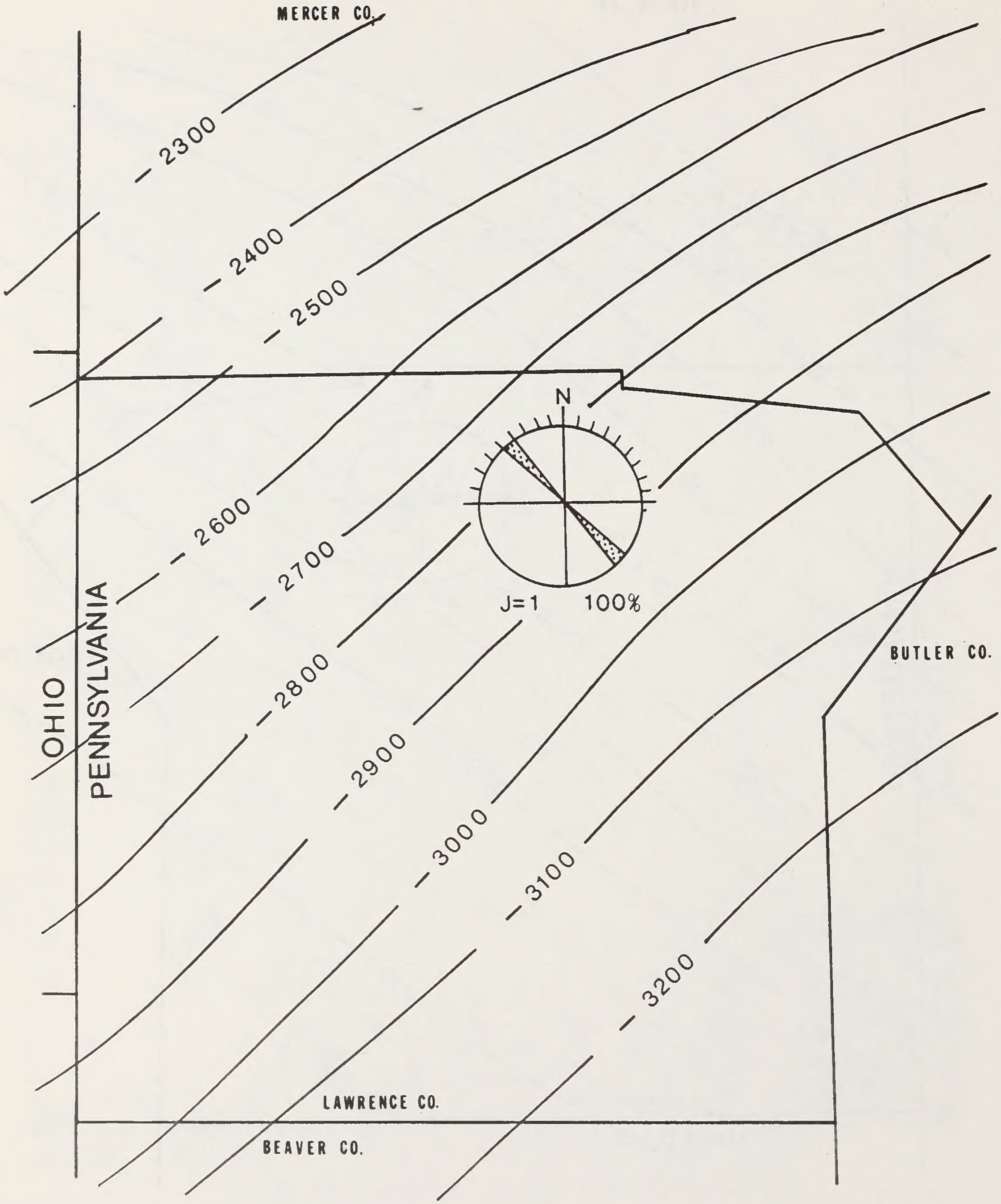
STRUCTURAL CONTOURS

BASE OF RHINESTREET

SCALE 1:250,000

FIGURE 5B

ROSE DIAGRAM: RHINESTREET



EGSP PENNSYLVANIA-5

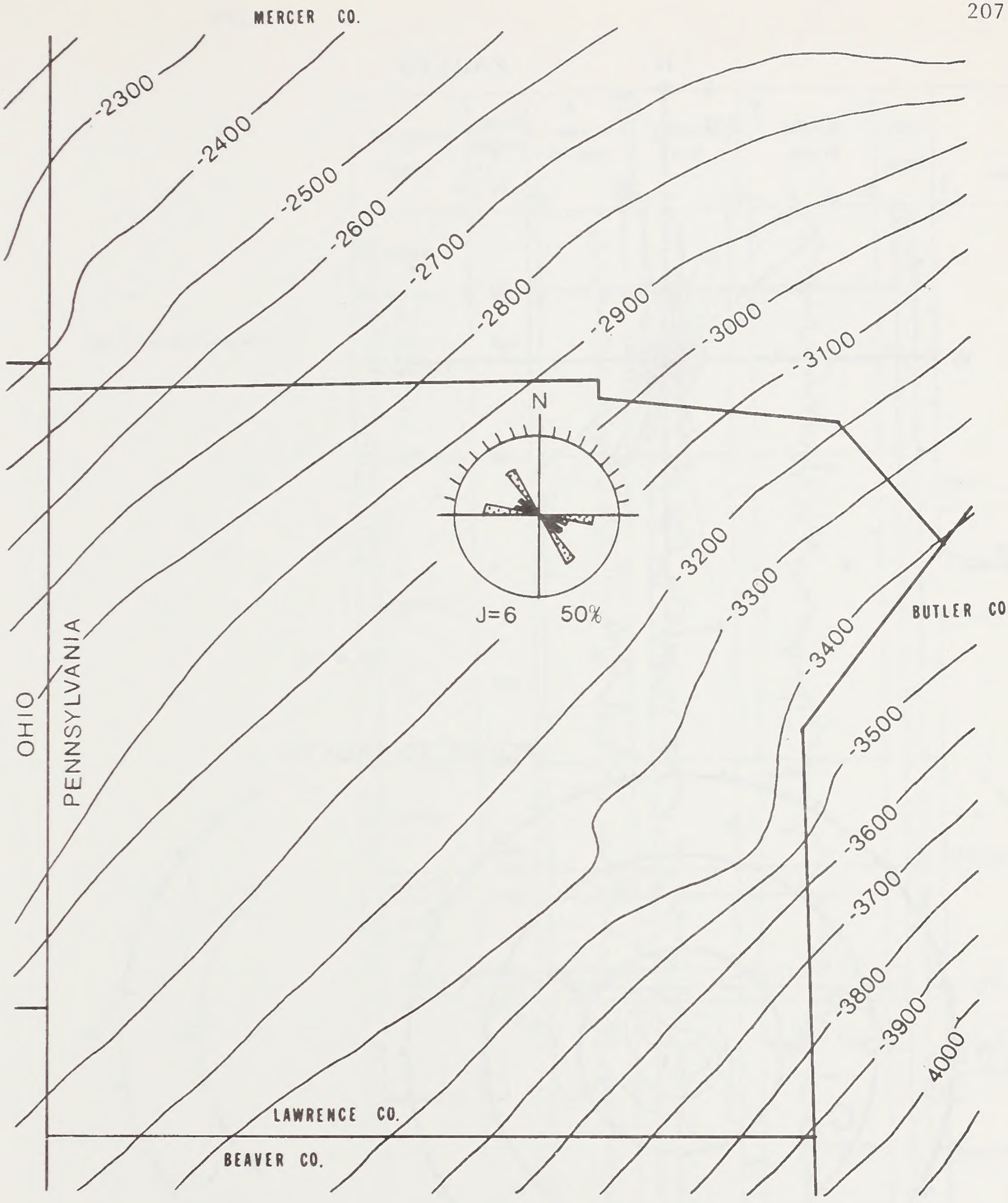
STRUCTURAL CONTOURS

BASE OF MIDDLESEX

SCALE 1:250,000

FIGURE 5C

ROSE DIAGRAM CASHAQUA



E.G.S.P. PENNSYLVANIA-5

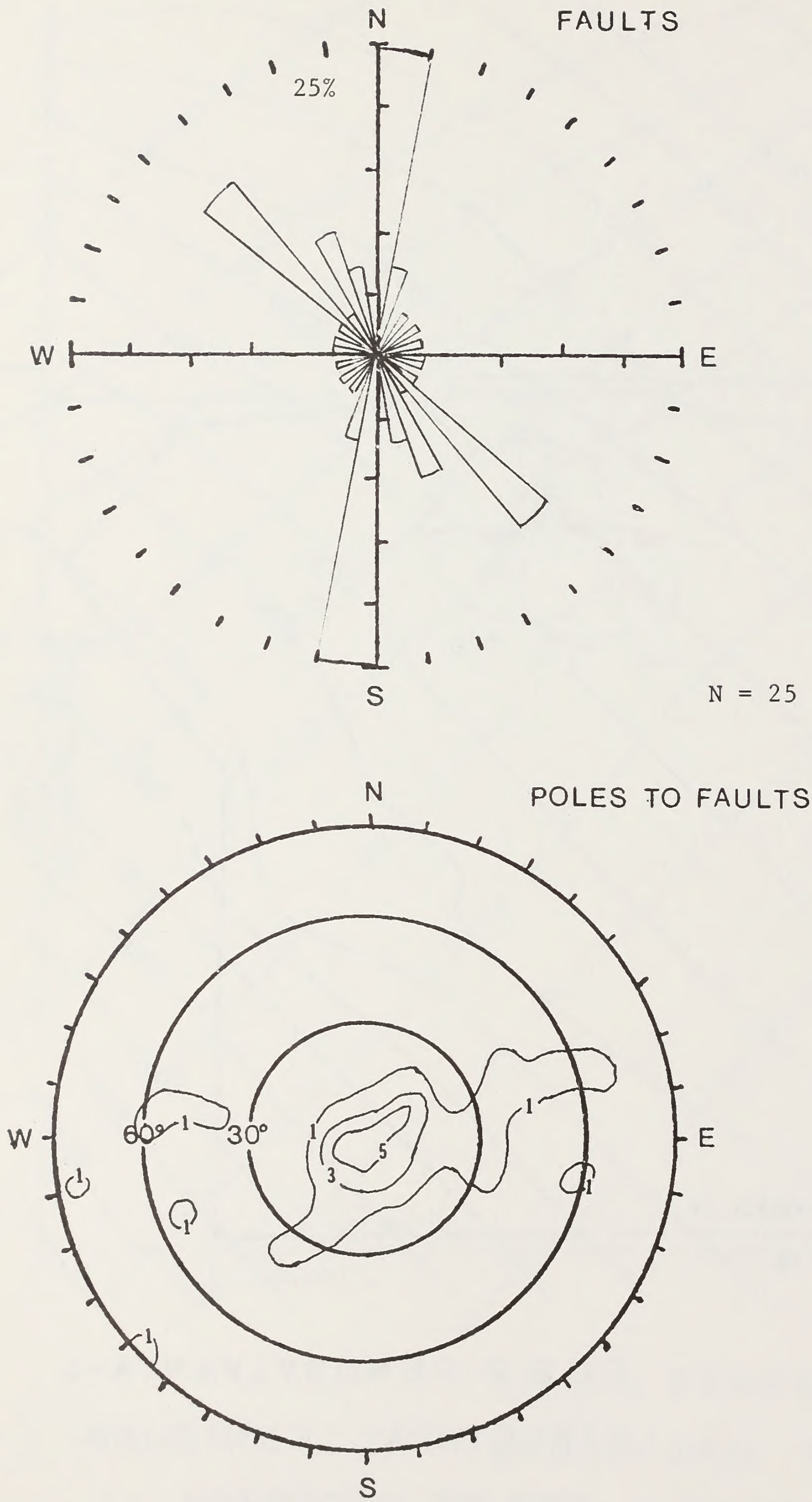
STRUCTURAL CONTOURS

TOP OF ONONDAGA

SCALE 1:250,000

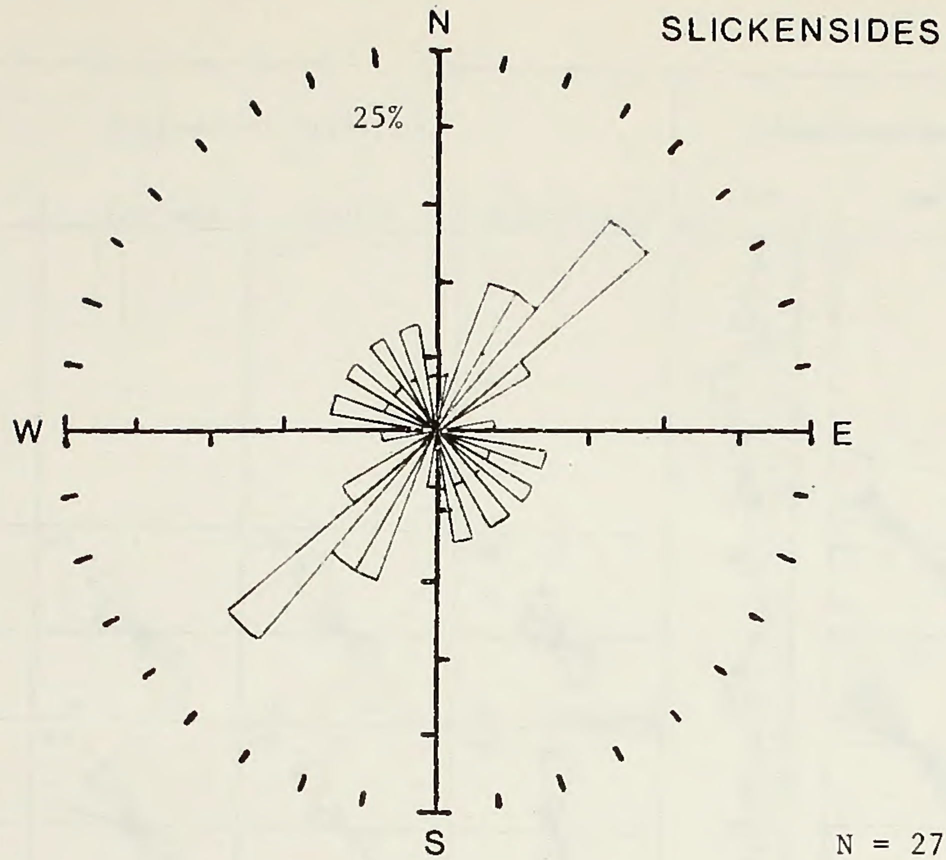
FIGURE 5D

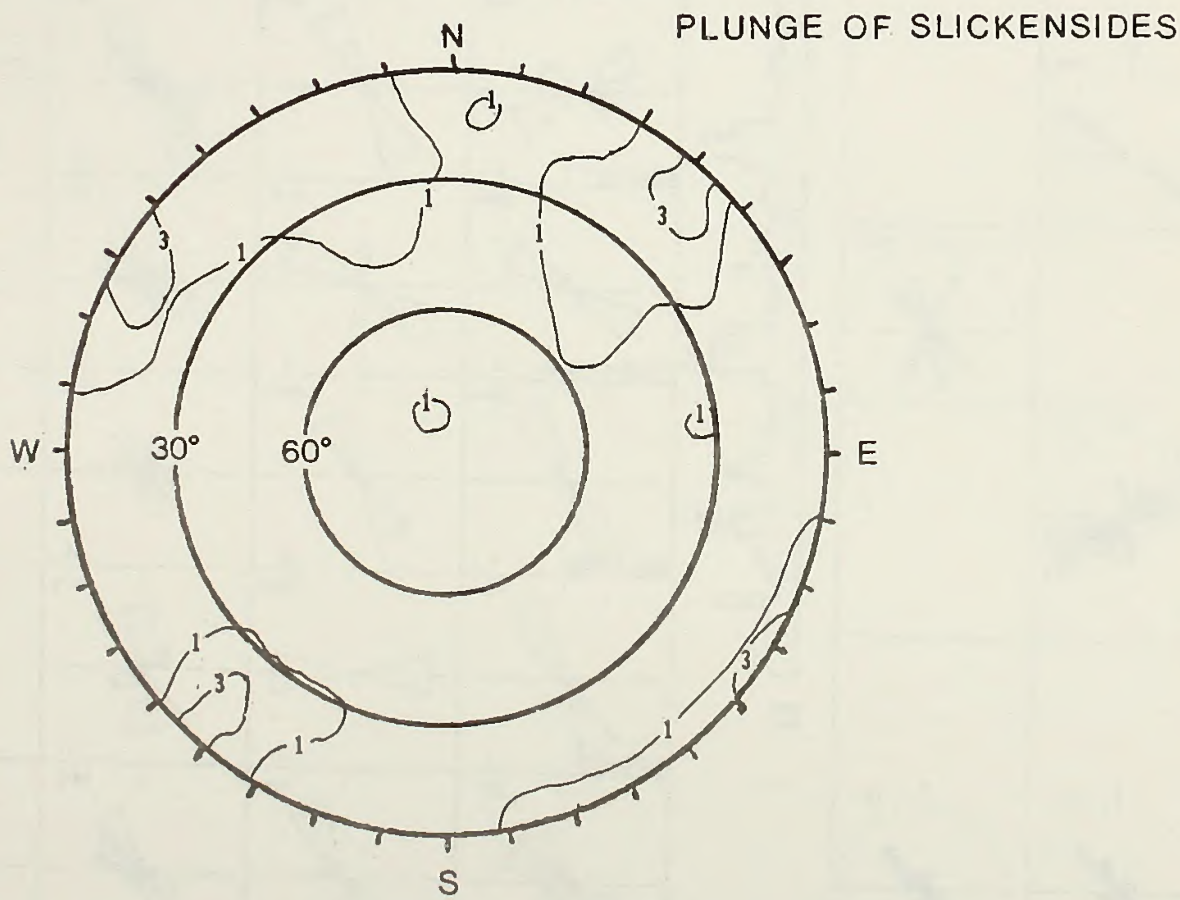
ROSE DIAGRAM: MAHANTANGO



EGSP-PENNSYLVANIA #5

Figure 5E. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.





EGSP-PENNSYLVANIA #5

Figure 5F. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.

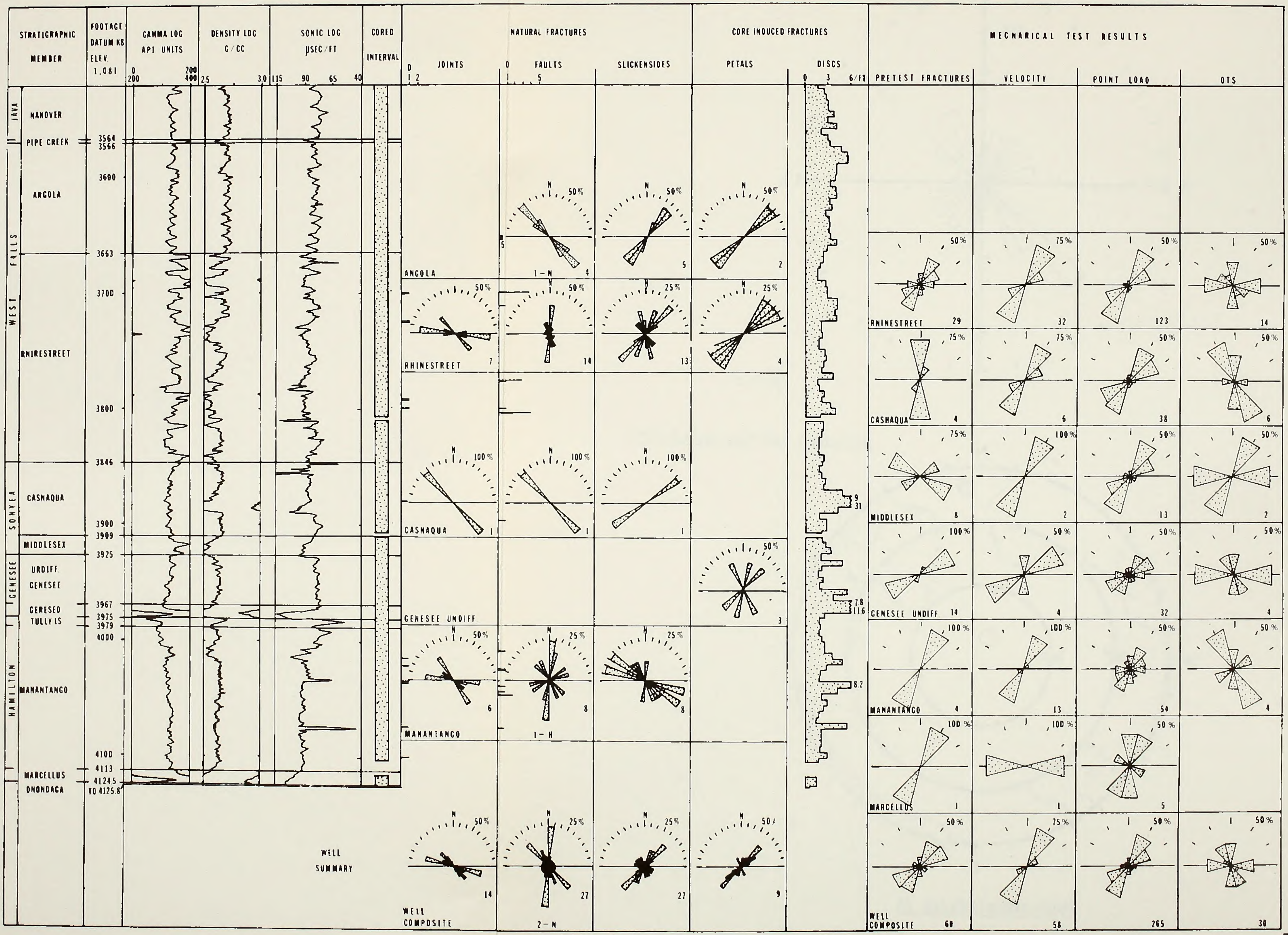


FIGURE 5G E.C.S.P. PENNSYLVANIA 5 WELL SUMMARY

"D" DISTRIBUTION OF FRACTURES
"H" HORIZONTAL

APPENDIX E

TENNESSEE EGSP WELLS

TENNESSEE #9: (GRUY FEDERAL #1) WELL

EGSP-TENNESSEE #9 (GRUY FEDERAL #1) WELL

LOCATION

The EGSP-Tennessee #9 well is located in the Avondale quadrangle of Grainger County, Tennessee, approximately seven miles east of Rutledge and two and one half miles south of the village of Thorn Hill. The exact position is 30°18'56"N by 82°24' 33"W at a ground level elevation of +1,140 feet MSL with the kelly bushing at +1,150 feet MSL (Figures 1, 9A and Table 1).

GEOLOGY

The surface topography near the well site consists of a series of northwest-trending valleys and ridges resulting from overthrusting. The well is located between the Greendale Syncline to the north and the Saltville Fault to the south. The Saltville Fault, which bounds the syncline to the southeast, is one of many thrust faults associated with the Pine Mountain Overthrust Belt (Figure 9A). The surface is underlain by rocks of the Conasauga Group (Middle Cambrian), Rome Formation (Cambrian), Grainger Formation (Mississippian-Upper Devonian), Chattanooga Shale (Upper Devonian), Wildcat Valley Sandstone (Lower Devonian), and Clinch Sandstone (Silurian). Ridges in the area are capped by the more resistant sandstones of the Rome and Grainger Formations, while the valleys contain the less resistant shales of the Pumpkin Valley (Conasauga Group) and the Chattanooga Shales (Cobb, et al., 1979) (Figure 9A).

The well was drilled to test the theory that a fracture reservoir may have been created by the thrust faulting. The location was selected

primarily on the basis of a seismic line run along strike six miles north of the well site and on the data of an earlier coring and logging program in the area (Gruy Federal, 1980).

Three intervals were cored: 1,167'-1,219', 1,610'-1,1739' and 1,820'-1,865' with 226' of core recovered. Coring-related information can be found in the well summary chart (Figure 9D).

PRODUCTION DATA

The well was stimulated with a foam-acid treatment from 1,630' to 1,850', an interval composed of the Lower Huron, Upper Olentangy and Rhinestreet Members. Some gas was encountered, but flow could not be maintained without continuous swabbing. The quantity of gas produced was not sufficient to warrant the swabbing, so the well was shut in with no commercial production having taken place (Horton, 1981). Since the Chattanooga Shale outcrops a mile and a half from the well, more gas may have originally been present but has escaped and has been replaced with water (Gruy Federal, 1980).

CORING-INDUCED FRACTURES

No petal fractures and relatively few disc fractures appeared in the EGSP-Tennessee #9 core, indicating greater than average tensile strength between bedding planes.

NATURAL FRACTURES

Of the 565 natural fractures identified in the core, 36% are joints and 64% are faults. Due to several highly faulted and fractured areas and some thrust faulting, only 456 of the fractures could be oriented. The greatest concentrations of fractures occur in the Lower Huron and

Rhinestreet Members with 3.31 and 4.45 fractures per foot, respectively. Many of the fractures are mineralized. Calcite mineralization occurs near the top of the core turning to dolomite through the middle section. The fractures near the bottom of the core are generally unmineralized (Cliffs Minerals, Inc. Phase II Report).

The joints have two major preferred orientations as can been seen on the well composite (Figure 9D). The major trend, which is the transverse joint set, is N30°-50°W with an 82°-90° dip. The secondary trend, or longitudinal joint set, is N40°-60°E with a 76°-90° dip. These joints are clearly a result of the stresses that folded and faulted this area. Individually, the stratigraphic members follow the same pattern, with the exception of the Olentangy Shale where the major trend is near east-west with a secondary trend near north-south. This anomaly may be the result of a changing stress field, or the shale may have reacted to the stress system in a slightly different manner.

Approximately one third of the faults found in the core strike northeast, parallel to the fold axes. This major preferred orientation is common to all members except the Sunbury-Cleveland Member whose faults have a N-S preferred orientation. This change in the Mississippian sediments may be the result of a detachment between the upper cored section and the Middle Huron Shale.

The overall preferred orientation of the slickensides is northwest and indicates movement in the direction of thrusting (Figure 9C and 9D). This trend is consistent with the preferred orientations of most of the individual members. Exceptions are the Sunbury-Cleveland with an

essentially random distribution and the Olentangy with a northern preferred orientation and a northwest secondary preferred orientation. The large number of faults in the Lower Huron defines a detachment at that level. As a result of the detachment, the underlying Olentangy Shale was probably subjected to a different stress system as shown by the change in orientation of joints, faults and slickensides.

A comparison of joints, faults and slickensides indicates that they have resulted directly from stresses that produced the folding and faulting that occurs in the Pine Mountain Overthrust. Joint and slickenside orientations are nearly perpendicular to the anticlines and synclines of the Pine Mountain Thrust Block.

MECHANICAL TEST RESULTS

The pretest fractures show a major N60°W preferred orientation, and a strong N30°E secondary preferred orientation in the well composite (Figure 9D). Inspection of individual members shows the northwest preferred orientation in all but the Lower Huron Member. Pretest fractures in the Lower Huron have two, equal preferred orientations (N30°W and N30°E) that are parallel to the transverse joint orientation.

The composite of the ultrasonic wave velocity test results shows a major preferred orientation of N60°E and a secondary preferred orientation of N90°E. Seven of the eleven velocity tests are in the Lower Huron, so Lower Huron data dominates the composite rose diagram. Therefore, the preferred orientations of the Sunbury-Cleveland and Middle Huron Members show in the composite as secondary orientations which

correlate with the natural fracture changes indicating a different stress system.

The composite rose diagram of the point load fractures is also dominated by the Lower Huron which contains half of the point load tests conducted. The major preferred orientation is N30°E with secondary trends to N60°E and north-south in the composite and in the Lower Huron. The preferred orientations of the other three members are also in one of these three directions. Point load test results also show that the Sunbury-Cleveland and Olentangy Members have been deformed differently than the other members.

The composite rose diagram for the DTS test results shows a strong preference for an E-W orientation. This change may be a result of the large number of faults in the shales. Limited hydrofracture tests display a N-S trend and do not correlate with any of the other tests. Taken together the composites of the mechanical tests do not indicate any strong preferred direction of fracturing. The pretest fractures have a N60°W preferred orientation. The ultrasonic velocities display a N60°E orientation, the point load data a N30°E trend, the DTS an E-W orientation and the hydrofractures a N-S trend. Some correlation exists between individual mechanical tests and natural fractures. The N60°W preferred orientation of the pretest fractures is nearly the same as the preferred orientations of the joints and slickensides. The scatter in the remaining tests may be explained by the deformation these rocks have been exposed to, thus creating varying fabrics or overprinting of previous deformations.

E.G.S.P. TENNESSEE-9 SURFACE GEOLOGY

FIGURE 9A

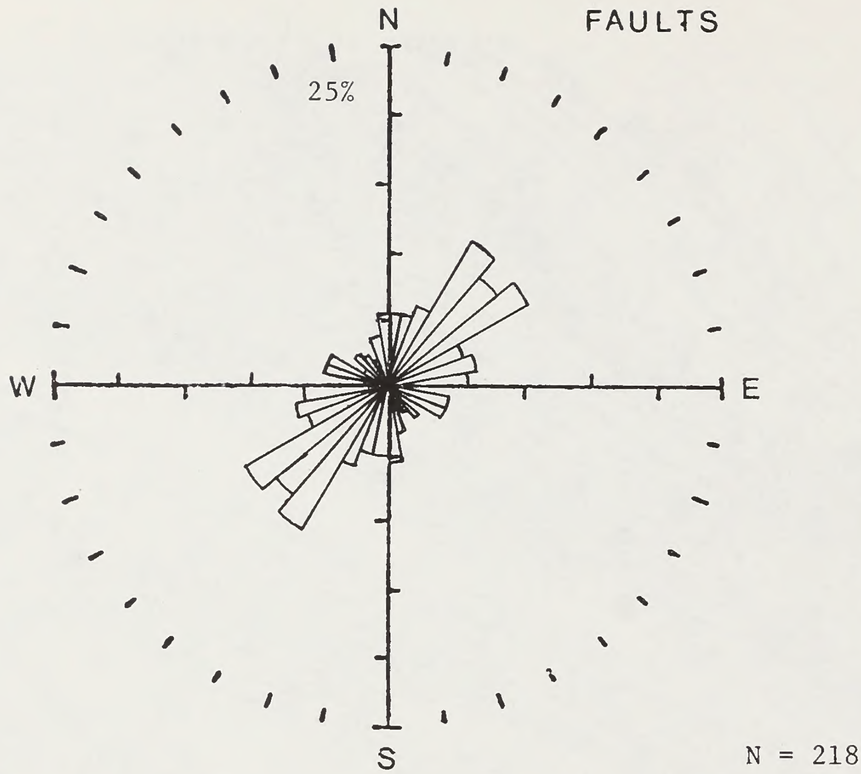
Mississippian: MDc, Mg, Mn & Mp.

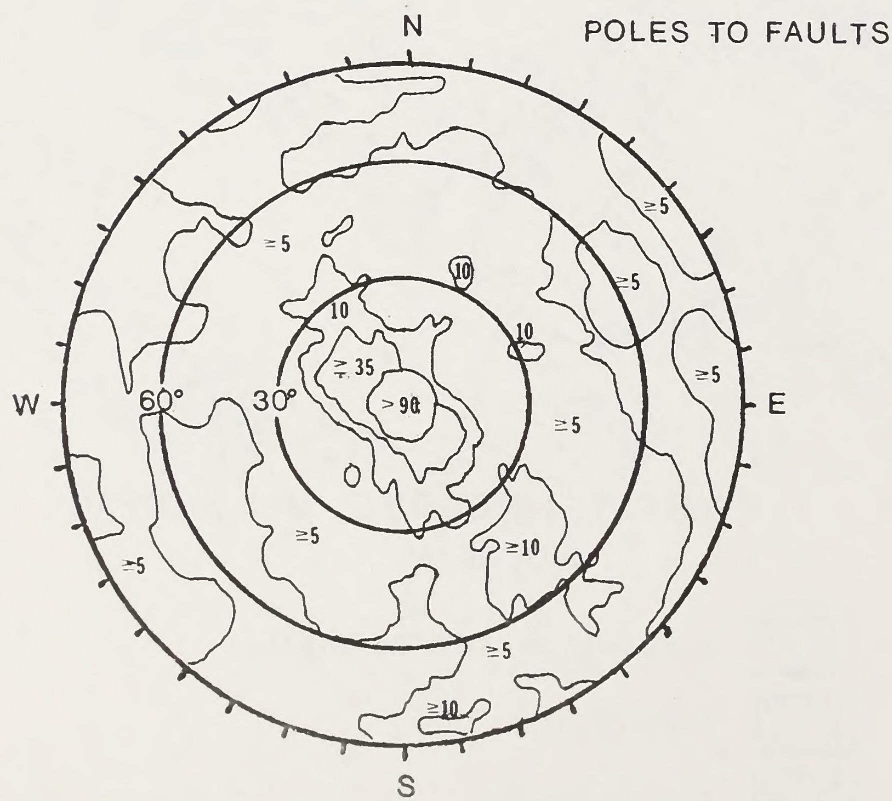
Devonian: DSs.

Silurian: Sc & Src.

Ordovician: Oc, Olv, Olc, On, Onc, Ock, Ol, Omlc, Och, Omb & Oj.

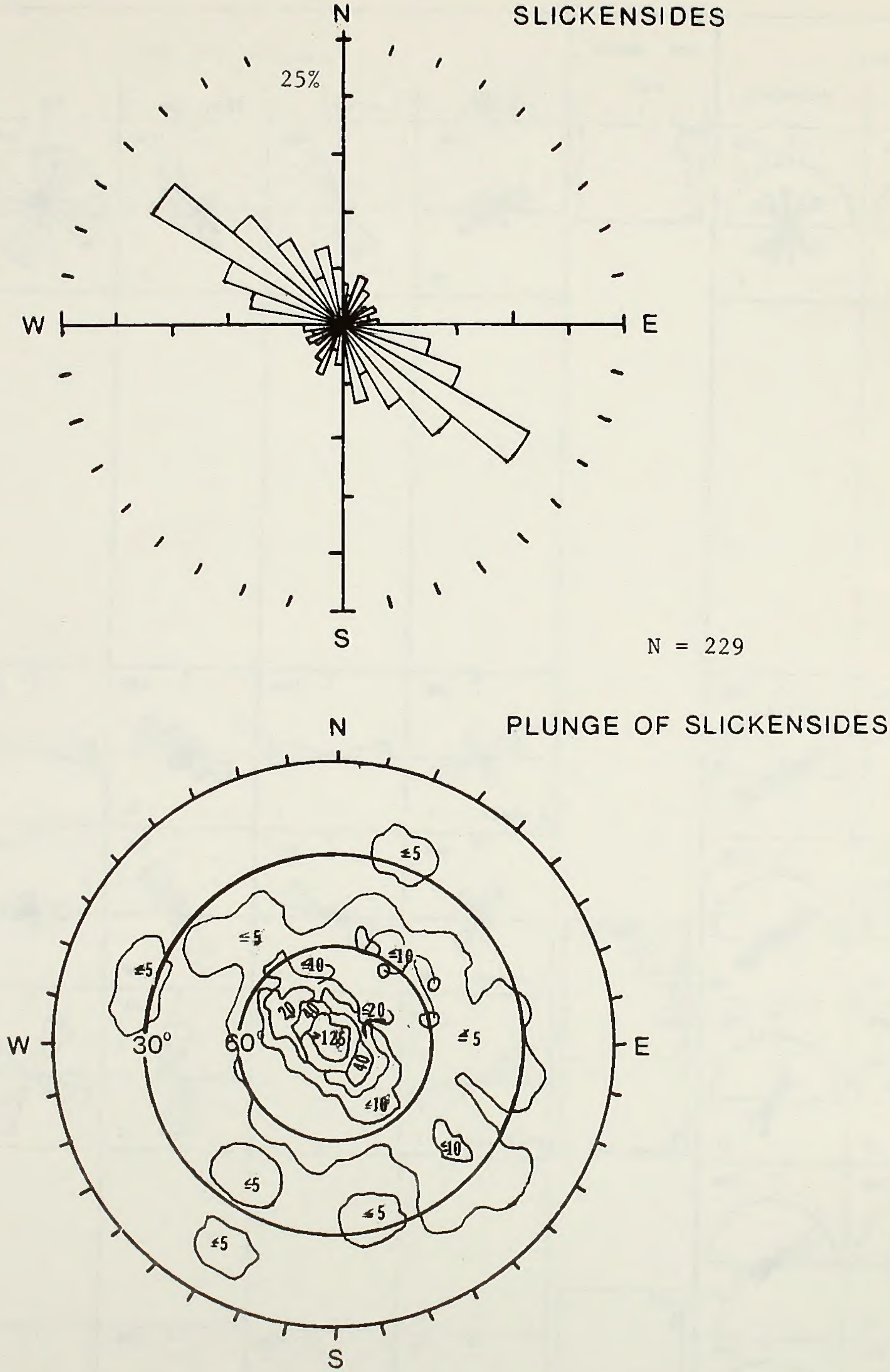
Cambrian: Cr, Cpv, Cmr, Cn, Cmn, Ccu, Ccl, Cc & Ccr.





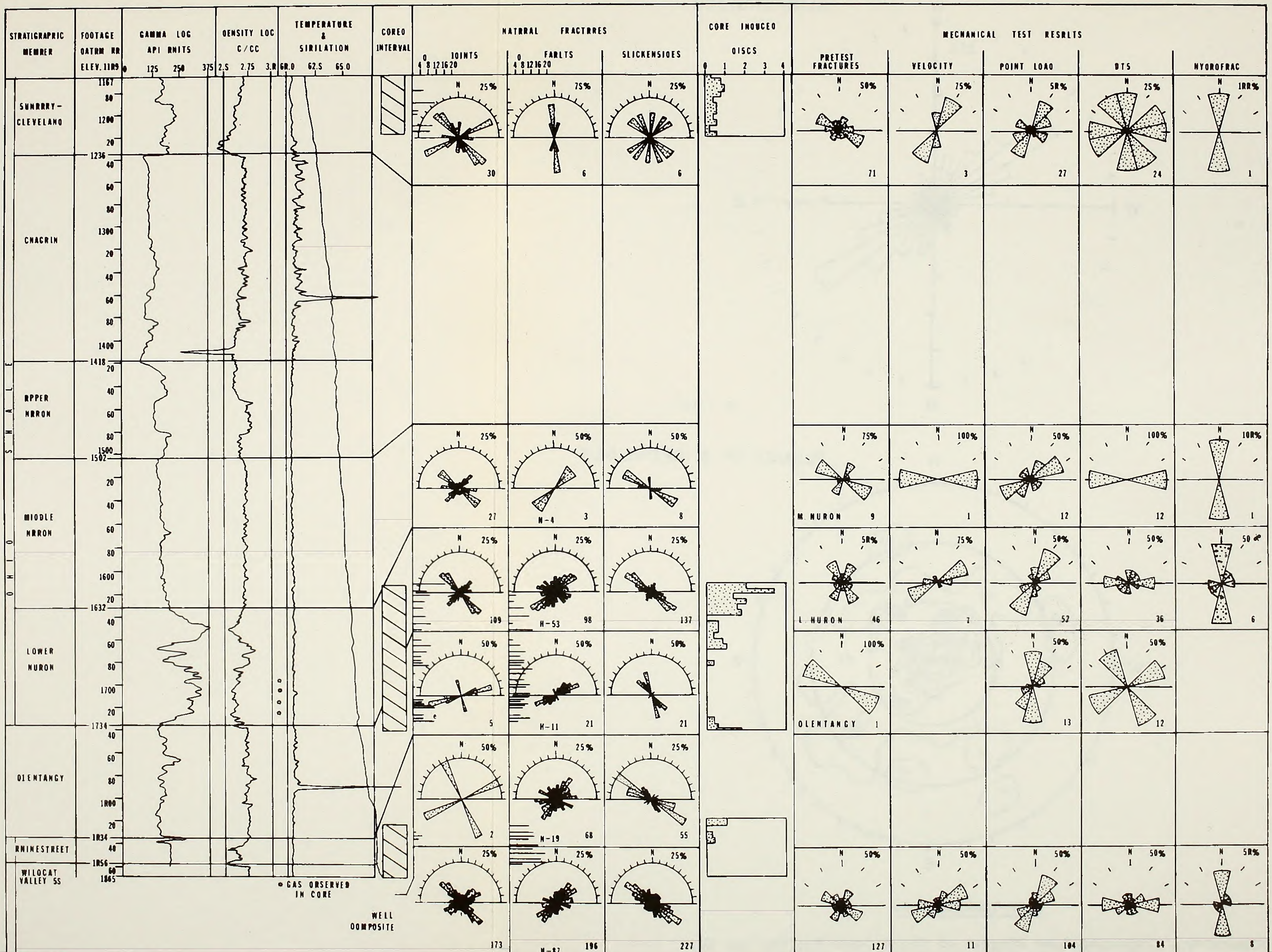
EGSP-TENNESSEE #9

Figure 9B. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.



EGSP-TENNESSEE #9

Figure 9C. Composite Rose Diagram of Slickenside Bearing and Equal Area Projection of Slickenside Plunge.



"D": DISTRIBUTION OF FRACTURES
"H": HORIZONTAL FRACTURES

FIGURE 9D EGSP-TENNESSEE #9 WELL SUMMARY

APPENDIX F

VIRGINIA EGSP WELLS

VIRGINIA #1: (PA-VA CORP. FARM WELL #20338) WELL

EGSP-VIRGINIA #1 (PA-VA CORP. FARM WELL #20338) WELL

LOCATION*[1]

The EGSP-Virginia #1 well is located in Wise County, Virginia, approximately ten miles southeast of the town of Whitesburg, Kentucky (Figures 1, 1A and Table 1).

GEOLOGY

The well site is located near the axis of the Middlesboro Syncline, approximately two miles southeast of the Pine Mountain Thrust Fault (Figure 1A). The fault and syncline axes strike approximately N60°E to a point northeast of the well where the fold structures display a more northerly strike. The thrust sheet is complex with more movement and shortening on the NE end compared to the southwest area. The bedrock well site area consists of Pennsylvanian sediments. A total of 380' of the Devonian was cored from two separate intervals: the first core point begins at 4,870' in the Mississippian Age Bedford Shale and ends at 4,985' in the Three Lick Bed; the second core is from 5,210' in the Middle Huron to 5,475' in the Lower Huron (Java?).

PRODUCTION DATA*[2]

Two intervals of the well were stimulated by a cryogenic-type treatment (gelled water and liquid CO_2), 4,890' to 4,910' in the Cleveland Member of the Ohio Shale and 5,450' to 5,480' in the Lower Huron Member of the Ohio Shale. After stimulation, the upper interval had an initial open flow fluctuating between 54 mcf/day and 107 mcf/day, and the lower interval had an initial open flow of 40 mcf/day (Komar, Frohne and Yost, 1978).

CORING-INDUCED FRACTURES*[3]

Coring induced petal fractures are the most common fracture type in the core. The petal fracture composite rose diagram (Figure 1D) has a peak at N50°-60°E with an average strike of N57°E. There is a 1.0% chance that this peak does not exist. Coring induced petal fracture orientations show very little variability with depth. The greatest change occurs between the Cleveland Member, interval 4,870'-4,930', and the Three Lick Bed, interval 4,931'-4,985', where mean strikes are N62°E and N43°E, respectively.

The dominant petal fracture orientation, N50°-60°E, is parallel to the Pine Mountain Thrust. This suggests that the tectonic compressive stresses which formed the thrust and the resulting layer-parallel shortening may have imposed a residual strain in the rocks in the form of an incipient cleavage (Engelder, 1979). This self-equilibrating recoverable strain may be responsible for the formation of the coring-induced fractures, alone or in combination with the maximum compressive stress.

NATURAL FRACTURES*[4]

Natural fractures occur throughout the Virginia #1 core. The Lower Huron Member, however, has a greater frequency of joints than other units cored (Figure 1D). The joint composite rose diagram has two significant peaks. There is a 1.0% chance that the peaks at N0°-20°W and N40°-60°W do not exist. Joint orientations vary from member to member suggesting that each unit reacted differently to the stress or each unit was stressed differently. Surfaces of nearly all the natural fractures are polished to some degree. However, since twist hackle and

hackle plume can be distinguished on most of these fracture surfaces, displacement along the fracture probably took place during or after fracture formation.

The N40°-60°W joint set is nearly orthogonal to the trace of the Pine Mountain Thrust and probably formed as an extension fracture set under tectonic compressive stresses during formation of the thrust. The N0°-10°W set and the smaller joint sets parallel faults and fold axes on the thrust sheet. The movement within the thrust sheet which formed these structures may be responsible for the three fracture sets.

FAULTS AND SLICKENSIDES*[5]

Faults are found to be concentrated in two zones: an upper zone at the contact of the Cleveland Member with the Three Lick Bed; and a lower zone which includes the entire Lower Huron Member, a soft black shale unit (Figure 1D). Faults are also scattered throughout the rest of the core. The two fault zones are vertically extensive and can be considered décollement zones. Whether the two slickenside zones are actually part of a single, much wider, décollement cannot be answered due to lack of data between the two cored intervals. Contours on blowout zones in the area (Young, 1957) fall near the top of the Lower Huron Member in the vicinity of this well. This agrees with the top of the lower décollement zone.

The fault composite rose diagram (Figure 1B) has a single peak at N40°-50°E with an average strike of N47°E. There is a 1.0% chance that this peak does not exist. Poles to slickensided surfaces form a girdle across the equal area projection (Figure 1C). The pattern of clusters

closely resembles the pattern of fracture dips which would be expected in a shear zone. The 0° dipping cluster in the center is the displacement shear cluster, the Riedel shear cluster dips 20°NW, and the thrust shear cluster dips 20°SE. R' shears may be present along the scatter in the southeast quadrant of the plot. In portions of the décollement zones the various sets of slip surfaces combine to divide the shear zone into numerous lenses. The lenses, usually bounded by Riedel and displacement shears, contain rock fragments so deformed as to be slickensided on all sides. Small fold and flow structures were also found in the lower décollement zone. Fault orientations show little variability (Figure 1D).

The slickenside composite rose diagram (Figure 1C) has a single peak at N50°-60°W. There is a 1.0% chance that this peak does not exist. The equal area projection of slickensides (Figure 1C) has two peripheral clusters which correspond to the low-dipping slickensides. There is very little scatter in slickenside trend (Figure 1D). Few of the slickensides are mineralized with massive barite being the most common type of mineralization.

The N40°-50°E fault trend parallels the trace of the Pine Mountain Thrust and the N50°-60°W trending slickensides are orthogonal to it. Therefore, it can be assumed that these structures reflect movement of the Pine Mountain Thrust sheet on décollement zones in the Devonian shales.

MECHANICAL TEST RESULTS

A series of mechanical tests was run at the MERC on the Virginia #1 core. The results are summarized in Figure 1D. The preferred orientation of the velocity tests in the Cleveland Shale matches that of the coring induced petal fractures at about N60°E. The faults also have a northeast preferred direction, while the point load tests have two peak preferred orientations, north and northeast. The latter is in agreement with the petal fracture and velocity data. Rose diagrams for the DTS tests in this well represent minimum tensile strength. Therefore, the preferred fracture orientation will be normal to the preferred orientation on the rose diagram. Thus, the DTS tests indicate a northeast preferred fracture orientation, in general agreement with the petal fractures and velocity tests and in partial agreement with the point load tests.

The Chagrin Shale test results show nearly the same pattern, with a preferred NE orientation of the petal fractures, faults, and velocity tests. As in the Cleveland Shale, the point load tests indicate north and N60°E preferred orientations. The DTS results are random with three tests and three orientations.

The Middle Huron also has similar preferred orientations with the petal fractures, faults and velocity test results all exhibiting a northeast preference. The point load tests evince a more northeasterly trend than in higher formations with equal preference for the north, N60°E and N30°E directions. Two of the four DTS samples indicate a north preferred direction.

The Lower Huron data also indicate a northeast preferred fracture direction with the faults, petal fractures, velocity tests and point load tests all indicating this preference. Two of the six DTS tests, however, show a preference for N30°W.

The well composite mirrors the results of the individual member data. The faults, petal fractures, velocity tests and DTS tests all show a northeast preferred fracture direction with the point load tests showing equal preference for the north and N60°E directions.

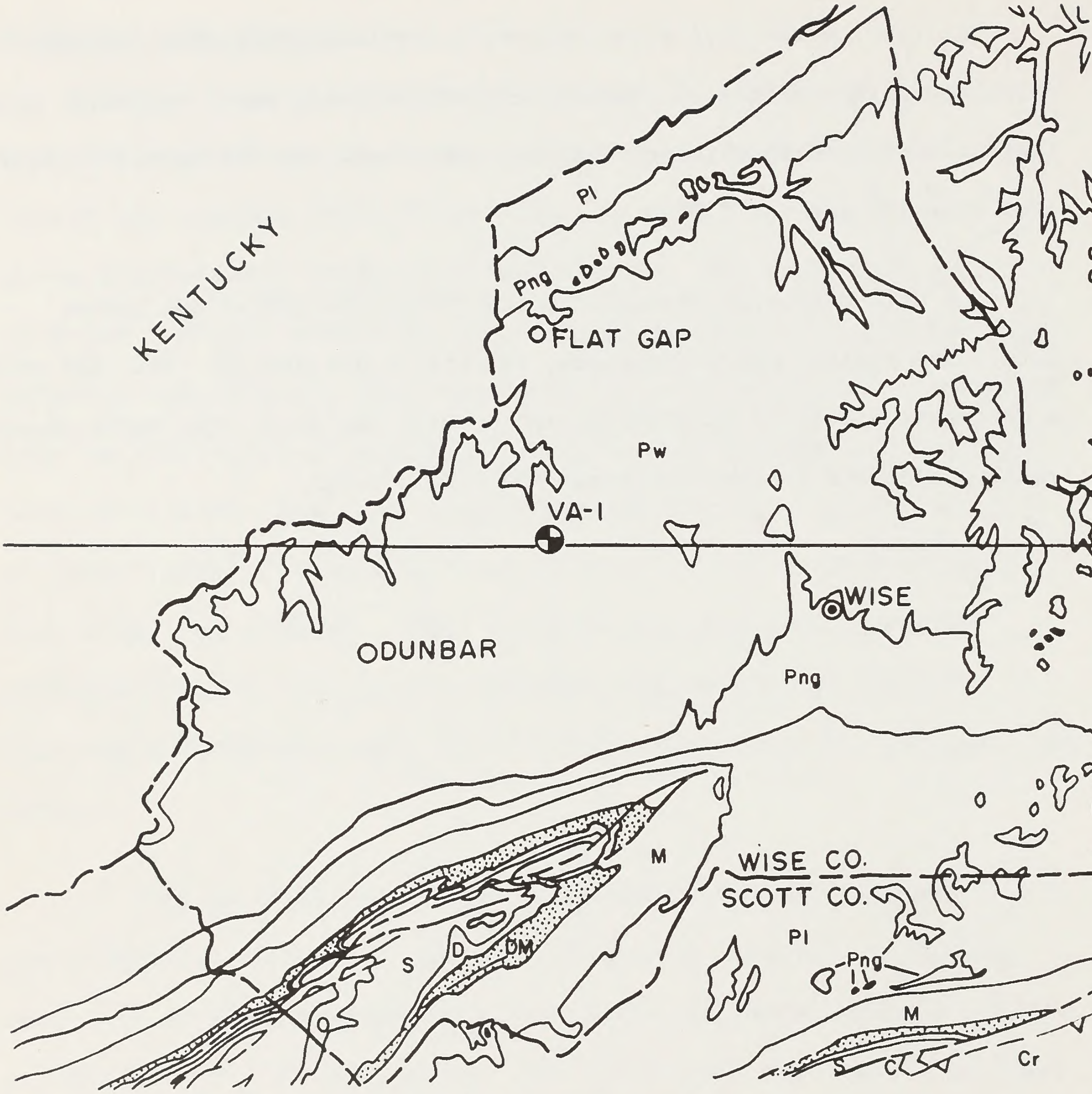
*[1] p. 196

*[2] p. 196

*[3] p. 196

*[4] p. 197

*[5] p. 198.



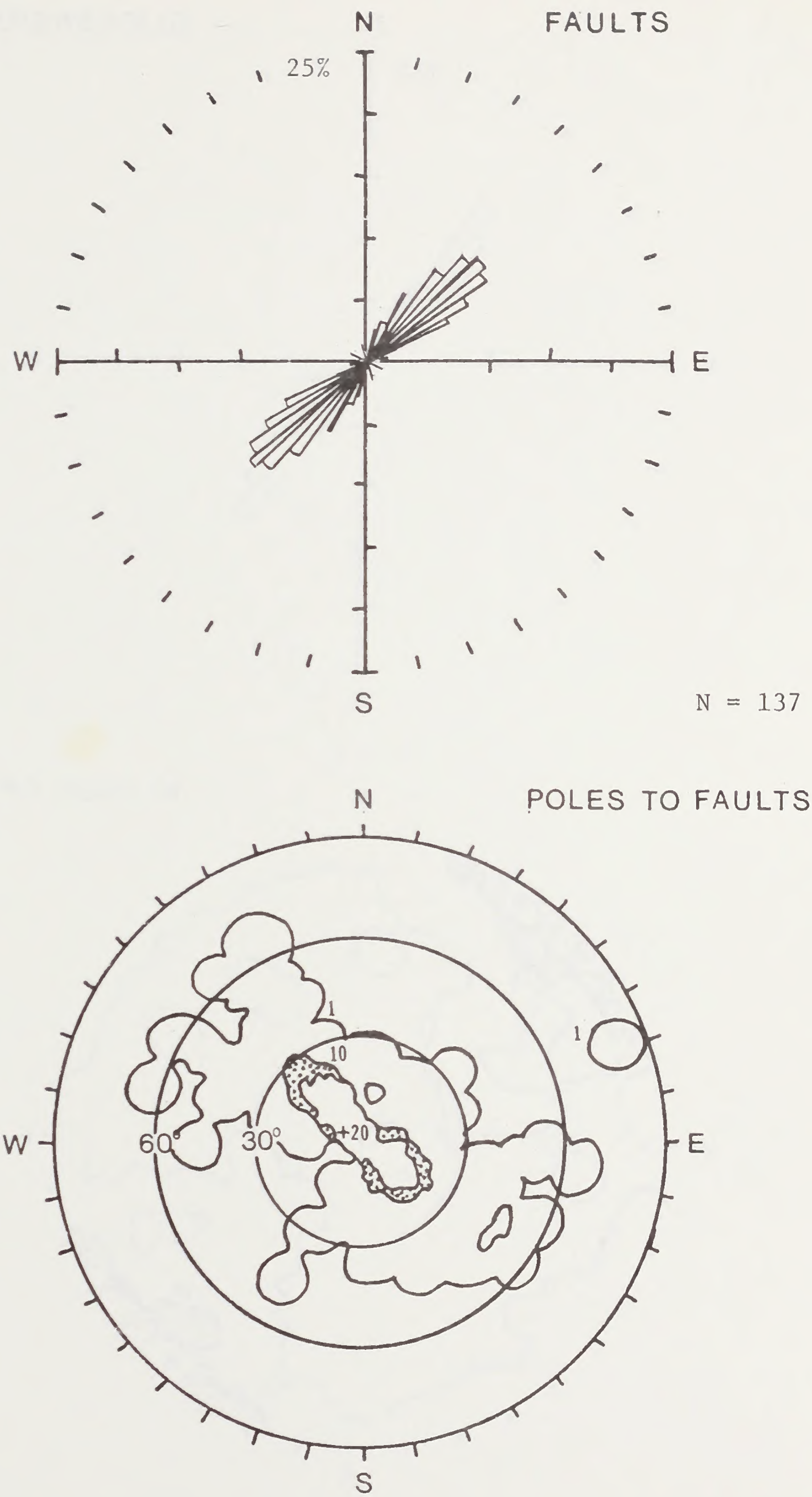
E.G.S.P. VIRGINIA-1
SURFACE GEOLOGY

LEGEND

Pw	Wise Formation	PENNSYLVANIAN
Png	Gladeville Sandstone	
Pl	Lee Formation	
M	MISSISSIPPIAN SEDIMENTS	
DM	DEVONIAN SHALES	
D	LOWER DEVONIAN	
S	SILURIAN SEDIMENTS	
O	ORDOVICIAN SEDIMENTS	
C-Cr	CAMBRIAN SEDIMENTS	

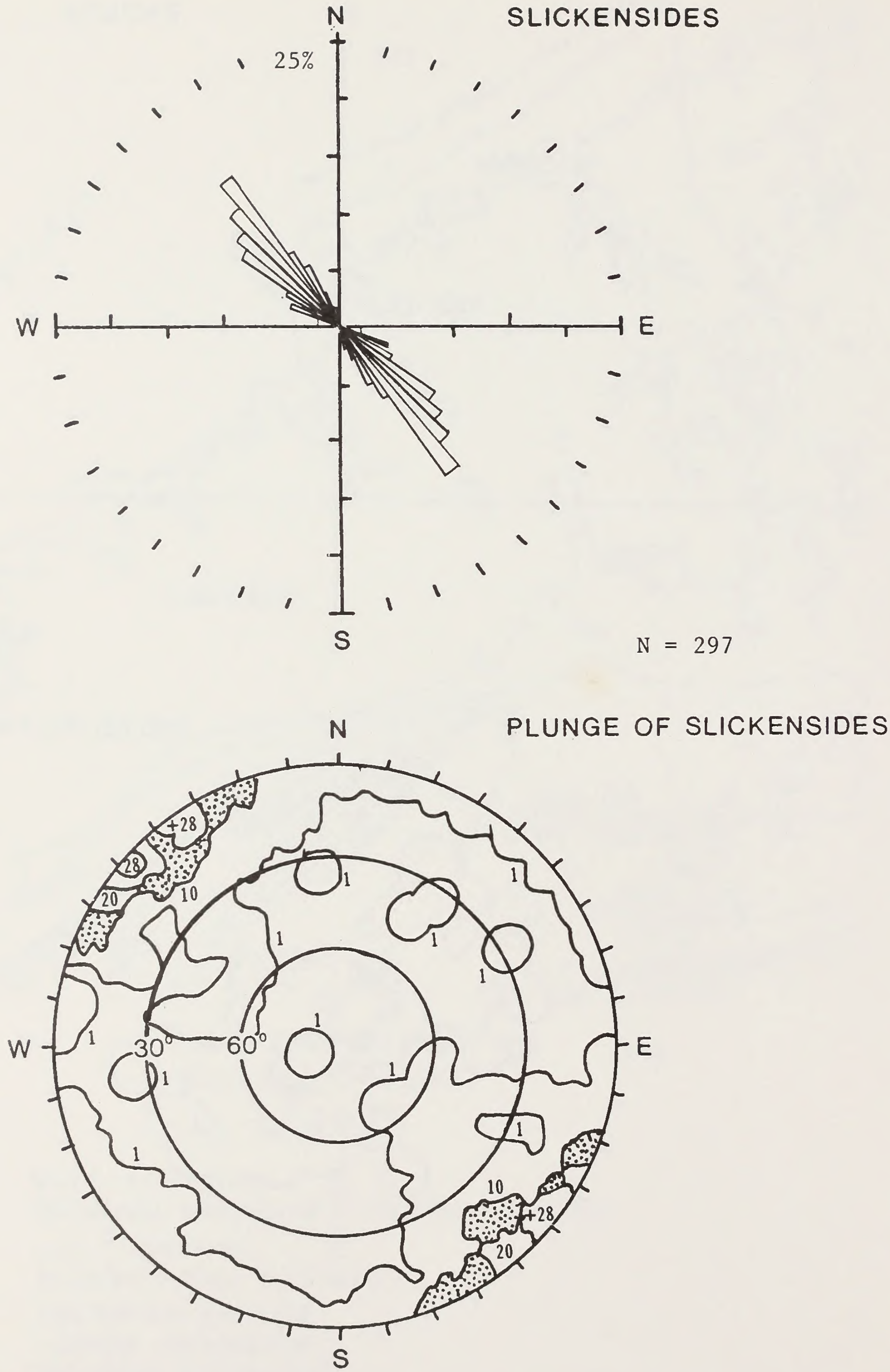
SCALE 1:250,000

FIGURE 1A



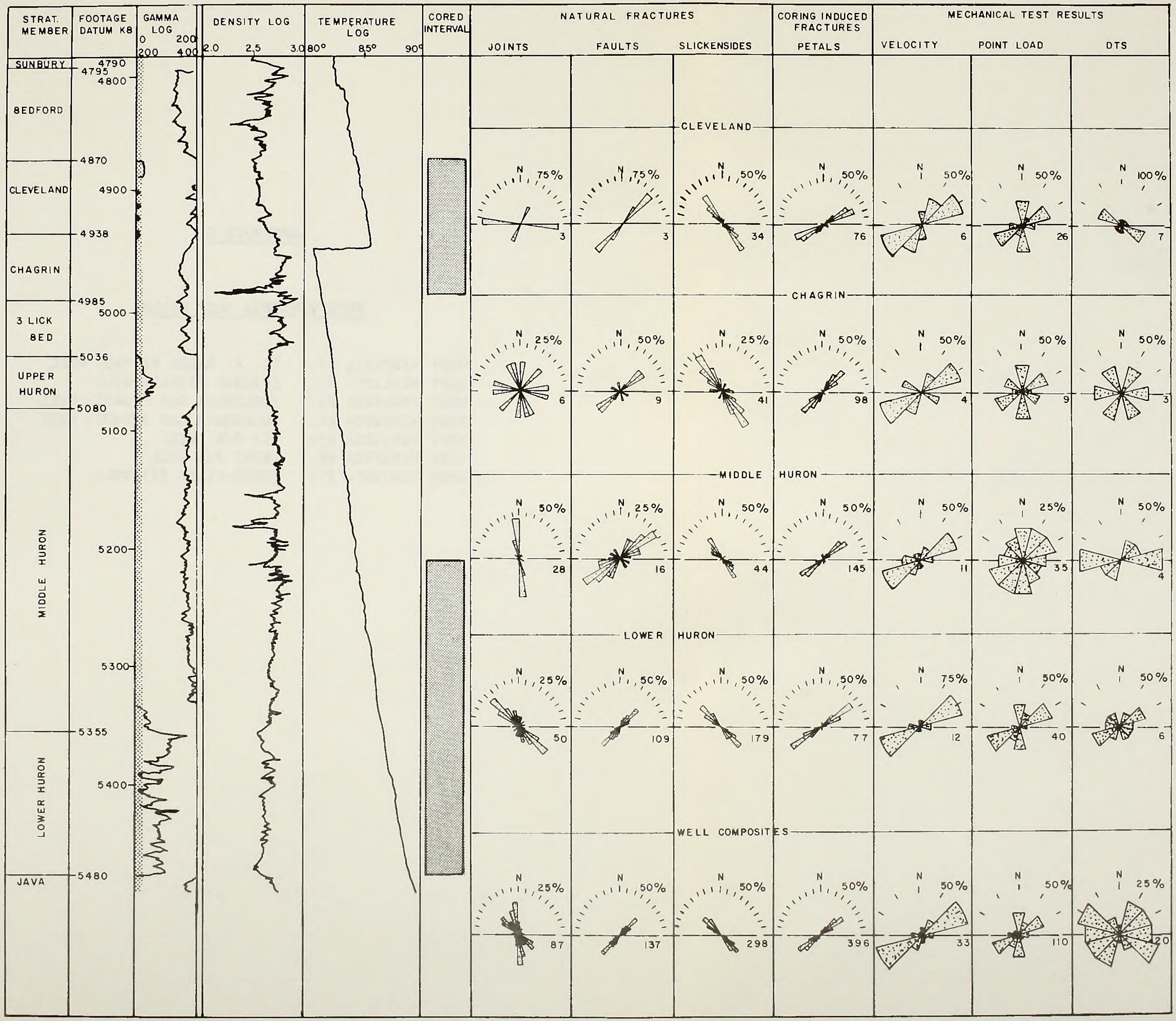
EGSP-VIRGINIA #1

Figure 1B. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Planes.



EGSP-VIRGINIA #1

Figure 4C. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.



EGSP VIRGINIA I WELL SUMMARY
FIGURE 1D

CLIFFS MINERALS, INC.

APPENDIX G

WEST VIRGINIA EGSP WELLS

WEST VIRGINIA #1:	(L. A. BALER #11940) WELL
WEST VIRGINIA #2:	(PINNEL #12041) WELL
WEST VIRGINIA #3:	(COLUMBIA GAS #20403) WELL
WEST VIRGINIA #4:	(COLUMBIA GAS #20402) WELL
WEST VIRGINIA #5:	(#3 D/K) WELL
WEST VIRGINIA #6:	(MERC #1) WELL
WEST VIRGINIA #7:	(EMCH-PYLES #1) WELL

EGSP-WEST VIRGINIA #1 (L. A. BALER #11940) WELL

LOCATION

The first EGSP well in West Virginia, EGSP-WV #1, is located near the Jackson-Mason County line, approximately 3.5 miles southwest of Cottageville, West Virginia (Figures 1, 1A and Table 1).

GEOLOGY

The well site is located at a point where surface structures display a marked change in strike from N70°E to N25°E (Geol. Map of WV, 1968) on the western edge of the Huntington-Pittsburgh Basin. Surface outcrop is composed of Upper Pennsylvanian-Permian Dunkard Group cyclic coal sediments. Major geologic structures include the Rome Trough to the south-southeast and the Burning Springs Anticline to the northeast. Detailed geology by Nuckols, 1979 indicates subtle flexures in the shale structure that are associated with gas production in the Cottageville Field (Figure 1F). The flexures and possible faulting are parallel to and probably the result of movement on faults in the Precambrian basement rocks as defined by seismic data (G. Sundheimer, 1979). This Precambrian fault system is associated with the Rome Trough structure. However, the strike of the basement faults changes and appears to parallel the aforementioned change in the surface folding from N70°E to N25°E, indicating a northerly trend for the west edge of the Rome Trough.

A total of 287' of core from two intervals was retrieved from EGSP-West Virginia #1. Confined to the Lower Huron Member of the Ohio Shale, the cores extend from 3,410' to 3,500' and from 3,600' to 3,797'.

PRODUCTION DATA

An initial flow of 1 mmcf was produced from the Lower Huron Shale and the well is now presumed to be in production.

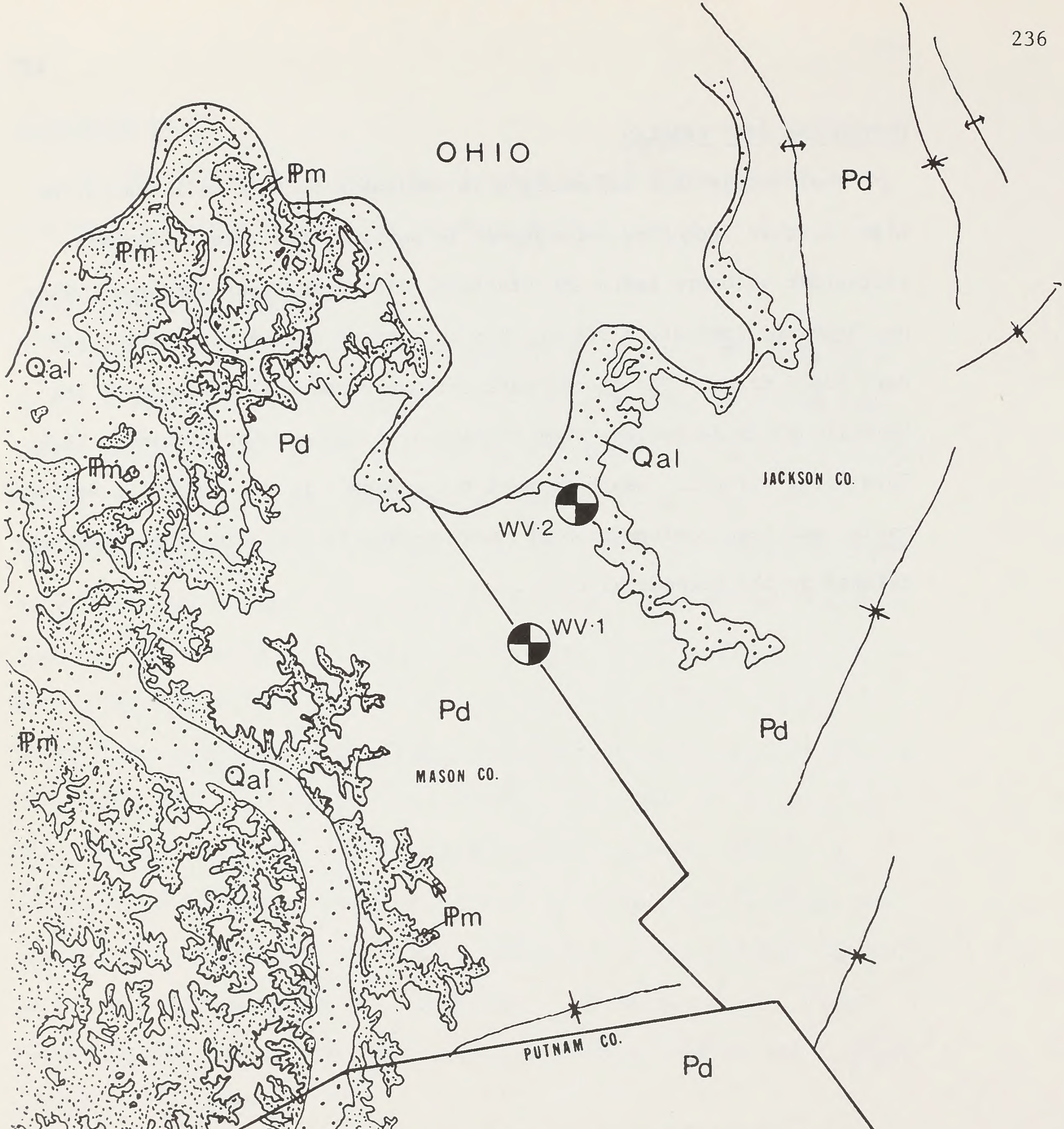
UNDIFFERENTIATED FRACTURES

The EGSP-West Virginia #1 well was one of the first wells drilled in the Eastern Gas Shales Project. In this early stage of determining what features should be recorded to properly analyze the Devonian Shales, natural and coring-induced fractures in the retrieved core were not differentiated. Notes made by Byrer, et al. (1976) and Larese and Heald (1976) and examination of the remains of the core lead to the conclusion that most of the fractures are coring induced petal centerline fractures with a consistent N40°-50°E strike. The zone from 3,720' to 3,796' shows a concentration of mineralized fractures (natural joints) oriented N10°-20°W, N40°-50°E and N80°-90°W (Figure 1E). Most of the gas production from the well comes from these mineralized joints. The N45°E coring induced fracture trend is parallel to the geological structures defined by Nuckols (1979) and may be indicative of the stresses developed in the NE trending flexure in the shales. The natural joints reflect trends parallel to the E-W fault system proposed by Nuckols and a trend normal to that system.

The most significant characteristic of the core from this well is the lack of natural joints in all but the Lower Member of the Ohio Shale and the consistent coring induced fracture trend suggesting that these rocks are under a stress that is insufficient to cause rupturing. Lack of rupturing within the flexure may restrict efforts to develop an Ohio Shale reservoir system in this area.

MECHANICAL TEST RESULTS

Very little test information is available on this well due to the high fracture frequency encountered in sampling the core. Only six ultrasonic velocity tests and nineteen point load tests were run. They do, however, indicate a primary N-S anisotropy in the rock with a secondary N30°E trend. The trends parallel the structural variance of the Rome Trough as determined from the magnetic map of West Virginia, 1978. This large structure may have been the greatest factor effecting sedimentation and later deformation of those sediments producing the anisotropy defined by the mechanical tests.



E.G.S.P WEST VIRGINIA-1,2 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

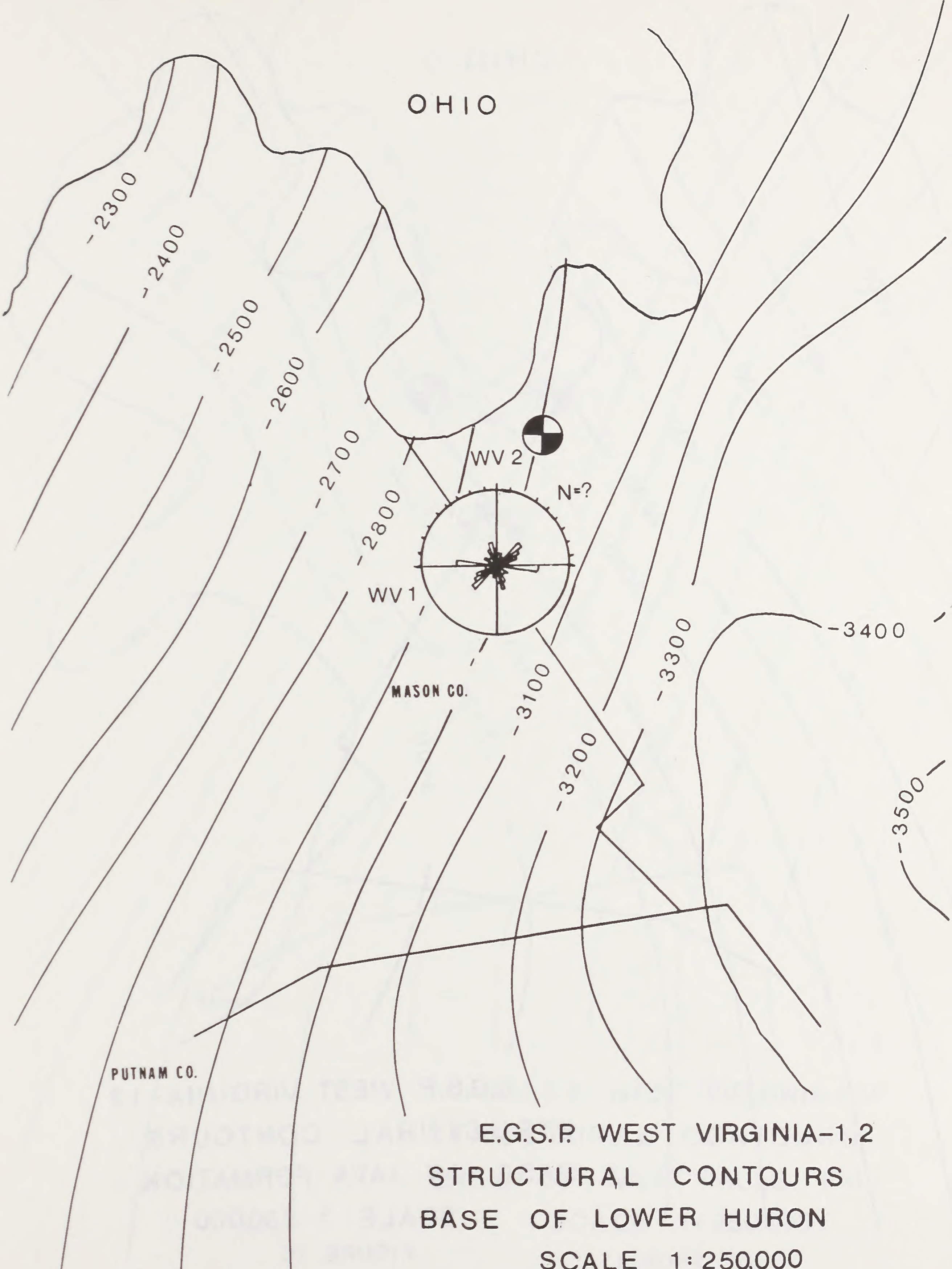
LEGEND

Qal	ALLUVIUM	Quaternary
Pd	DUNKARD Gp.	Perm. or Penn.
Pm	MONONGAHELA Gp.	Pennsylvanian

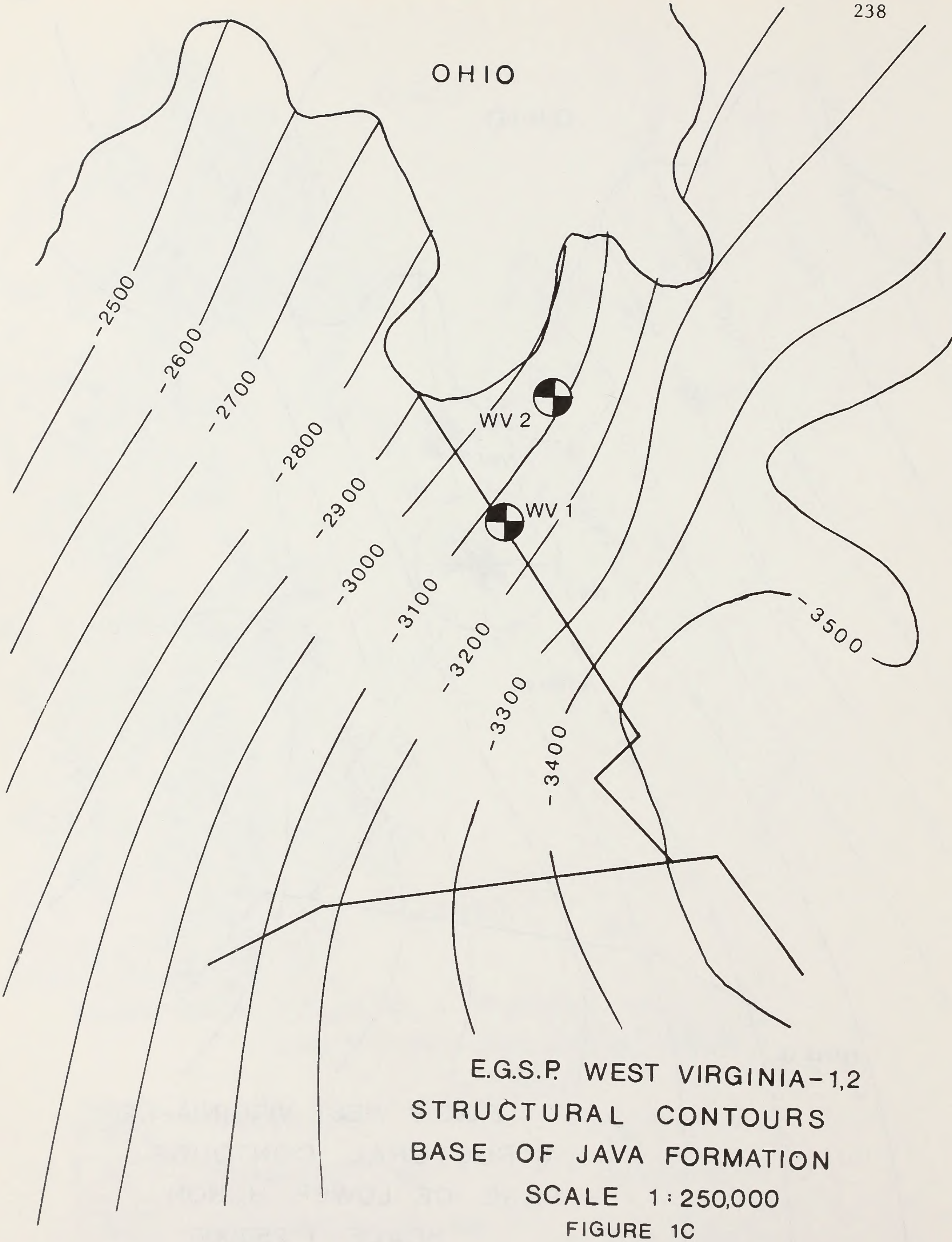
ANTICLINE SYNCLINE

SCALE 1 : 250,000

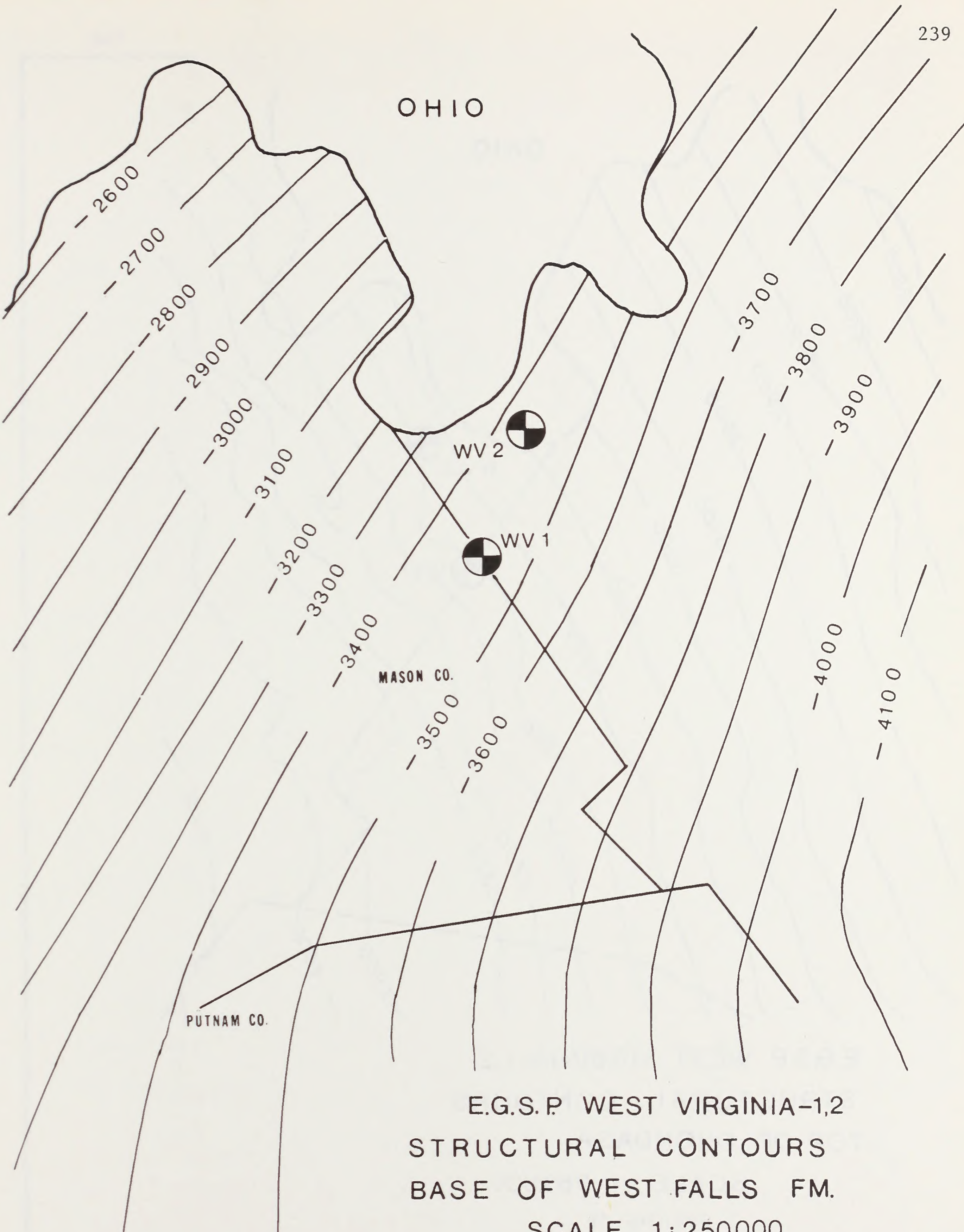
FIGURE 1A



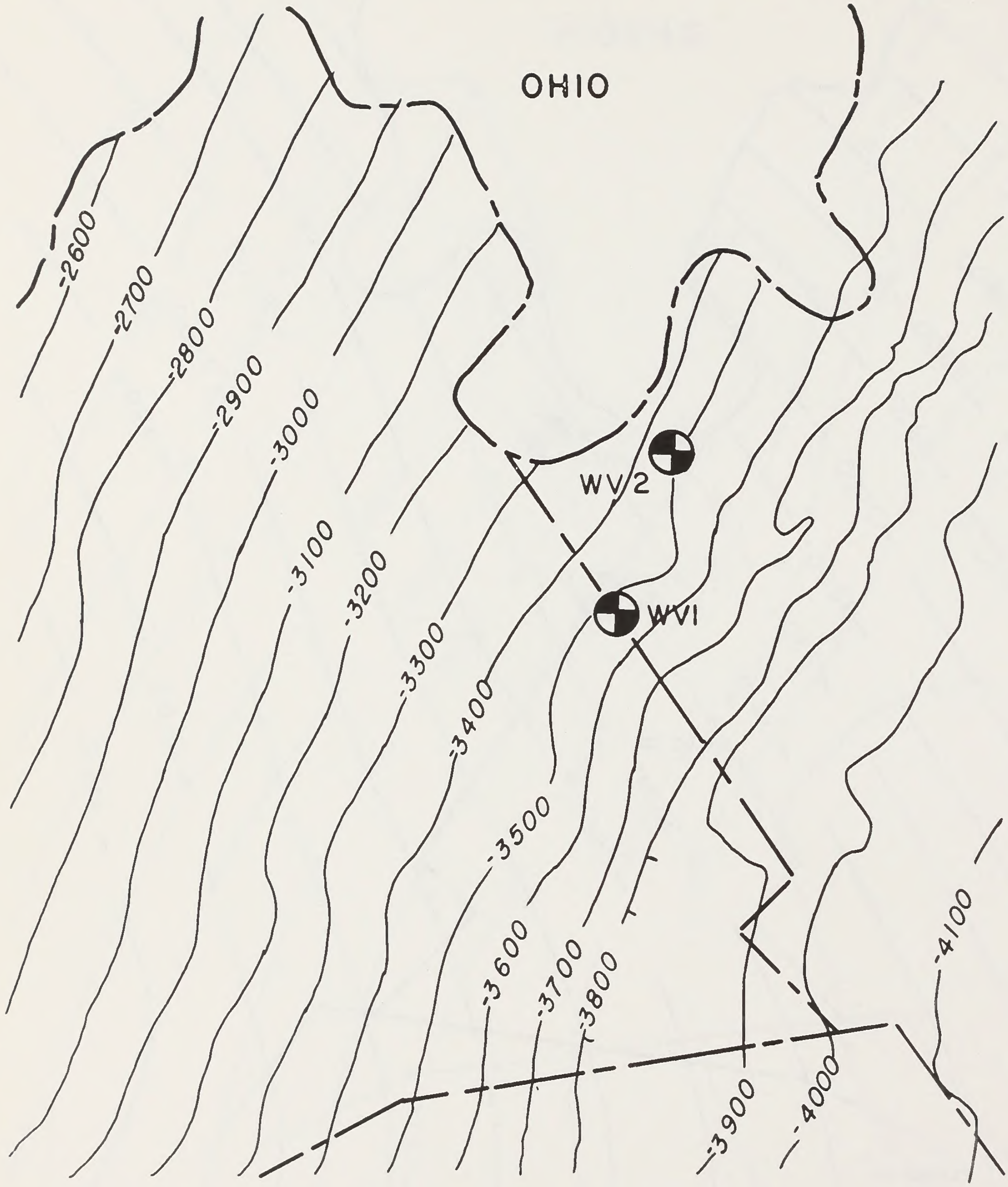
E.G.S.P. WEST VIRGINIA-1, 2
STRUCTURAL CONTOURS
BASE OF LOWER HURON
SCALE 1:250,000
FIGURE 1B



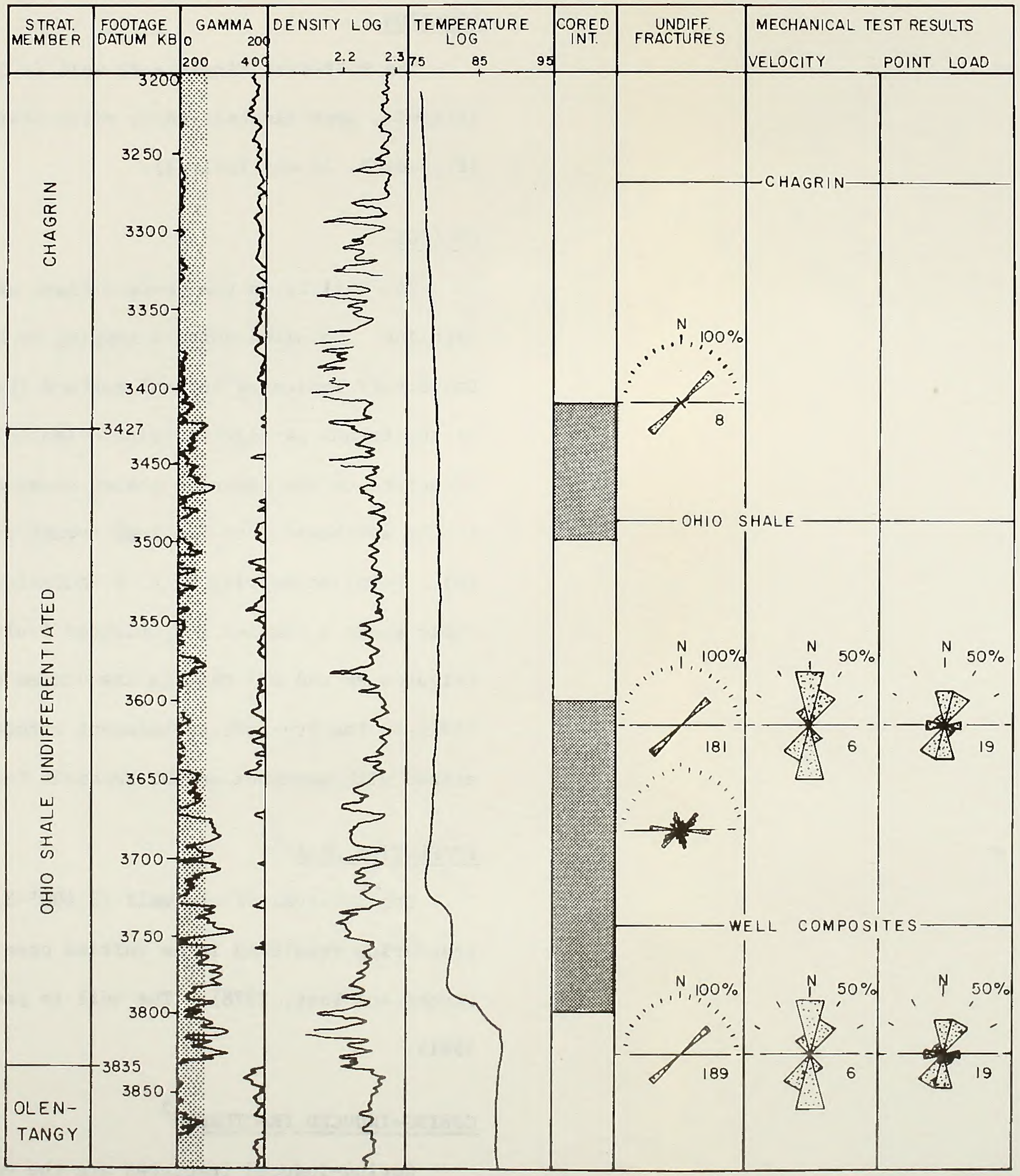
E.G.S.P. WEST VIRGINIA-1,2
STRUCTURAL CONTOURS
BASE OF JAVA FORMATION
SCALE 1:250,000
FIGURE 1C



E.G.S.P. WEST VIRGINIA-1,2
STRUCTURAL CONTOURS
BASE OF WEST FALLS FM.
SCALE 1:250,000
FIGURE 1D



E.G.S.P. WEST VIRGINIA-1,2
STRUCTURAL CONTOURS
TOP OF ONONDAGA
SCALE 1:250,000
FIGURE 1E



EGSP WEST VIRGINIA I WELL SUMMARY
FIGURE 1F

CLIFFS MINERALS, INC.

EGSP-WEST VIRGINIA #2 (PINNEL #12041) WELL

LOCATION

The EGSP-West Virginia #2 well is located in Jackson County, West Virginia, approximately three miles west of the town of Cottageville (Figures 1, 2A and Table 1).

GEOLOGY

The well is on the western flank of the N60°E trending Parkersburg Syncline. Detailed surface mapping by E. B. Werner of West Virginia University indicates several surface fracture trends (Figure 2A). Some of the trends paralleled joint orientations in the core. Regional structure of the Devonian Shales shows a monoclinal dip of less than 1° to the southeast into the Rome Trough structure (Figures 2B, 2C, and 2D). Detailed mapping by E. B. Nuckols in 1978 in the Cottageville gas field shows a complex E-W oriented fault system in the Devonian Shales (Figures 2F and 2G) that is associated with a normal fault striking N50°E in the Precambrian basement structure. Joint occurrence is associated with movement on the basement fault.

PRODUCTION DATA*[1]

One interval of the well (3,400'-3,560') was stimulated by foam fracturing resulting in an initial open flow of 180 mcf/day (Komar, Frohne and Yost, 1978). The well is presently in production (Horton, 1981).

CORING-INDUCED FRACTURES*[2]

Coring-induced fractures are the most common fracture type in the core. The lower portion of the Lower Huron Member of the Ohio Shale

and the Java Formation tend to have a greater abundance of coring-induced fractures than the other units. The orientations of only a portion of the coring-induced fractures were measured due to the poor condition of the core. The composite rose diagram of coring induced fracture strikes (Figure 2I) has two peaks. There is a 1.0% chance that the peak at N50°-70°E does not exist, and a 5.0% chance that the peak at N17°W does not exist. Coring induced fracture orientations change dramatically from a N50°-70°E trend to a N17°W trend at 3,679', which is 10 feet above the top of the Java Formation. Two subhorizontal slickensides are also found at this point. This change in orientation indicates an almost 90° swing in a stress or rock fabric anisotropy. The swing may be the effect of altered stress fields in the Java Formation caused by differential movement below the slip plane which has also been noted in other wells. The consistent N50°-70°E orientation may be related to the general east to northeast trending maximum compressive stress present in most of eastern North America (Sbar and Sykes, 1973).

NATURAL FRACTURES*[3]

Natural fractures are found only in the Lower Huron Member of the Ohio Shale, above the slickenside zone. Below that point, in the Java Formation, no natural fractures were found, probably resulting from altered stress fields in the Java Formation. The natural fracture composite rose diagram (Figure 2I) has a single peak at N57°E. There is a 1.0% chance that this peak does not exist. There is very little scatter in natural fracture orientation with depth. None of the natural fractures in the West Virginia #2 core are mineralized.

The N50°-60°E natural fracture set parallels the dominant coring induced fracture trend and may have formed under the same stress conditions which formed the coring-induced fractures. The fractures in this set are also subparallel to slickenside trends in the core and may have formed as extension fractures under compression from the northeast during formation of the Burning Springs Anticline.

FAULTS AND SLICKENSIDES

Faults are found in only two distinct zones, both of which are located near viscosity boundaries in the shale (Figure 2I). The upper zone, at 3,544', is in a thin high-organic shale layer immediately below a harder shale layer. The lower zone, at 3,641', is in a high organic shale near the base of the Lower Huron Member of the Ohio Shale, immediately above the harder grey shales of the Java Formation. The fault composite rose diagram (Figure 2G) has a single peak at N05°-20°W. There is a 1.0% chance that this peak does not exist. The equal area projection of poles to fault plane surfaces has two clusters, dipping 10°SW and 30°SW, respectively. Fault orientations do not change with depth and none of the slickensides in this core are mineralized.

The slickenside composite rose diagram (Figure 2H) has a single peak at N77°E. There is a 1.0% chance that this peak does not exist. The equal area projection of slickensides indicates two low-dipping clusters corresponding to the N77°E trend. Slickenside orientations do not change with depth or stratigraphy.

The two fault occurrences, because of their limited number and extent, cannot be considered décollement zones. However, they may be

slip planes which formed as the rock absorbed the remaining stresses of dying out detachments to the east. The N77°E displacement trend suggests a relationship with the detached Burning Springs Anticline to the northeast.

MECHANICAL TEST RESULTS

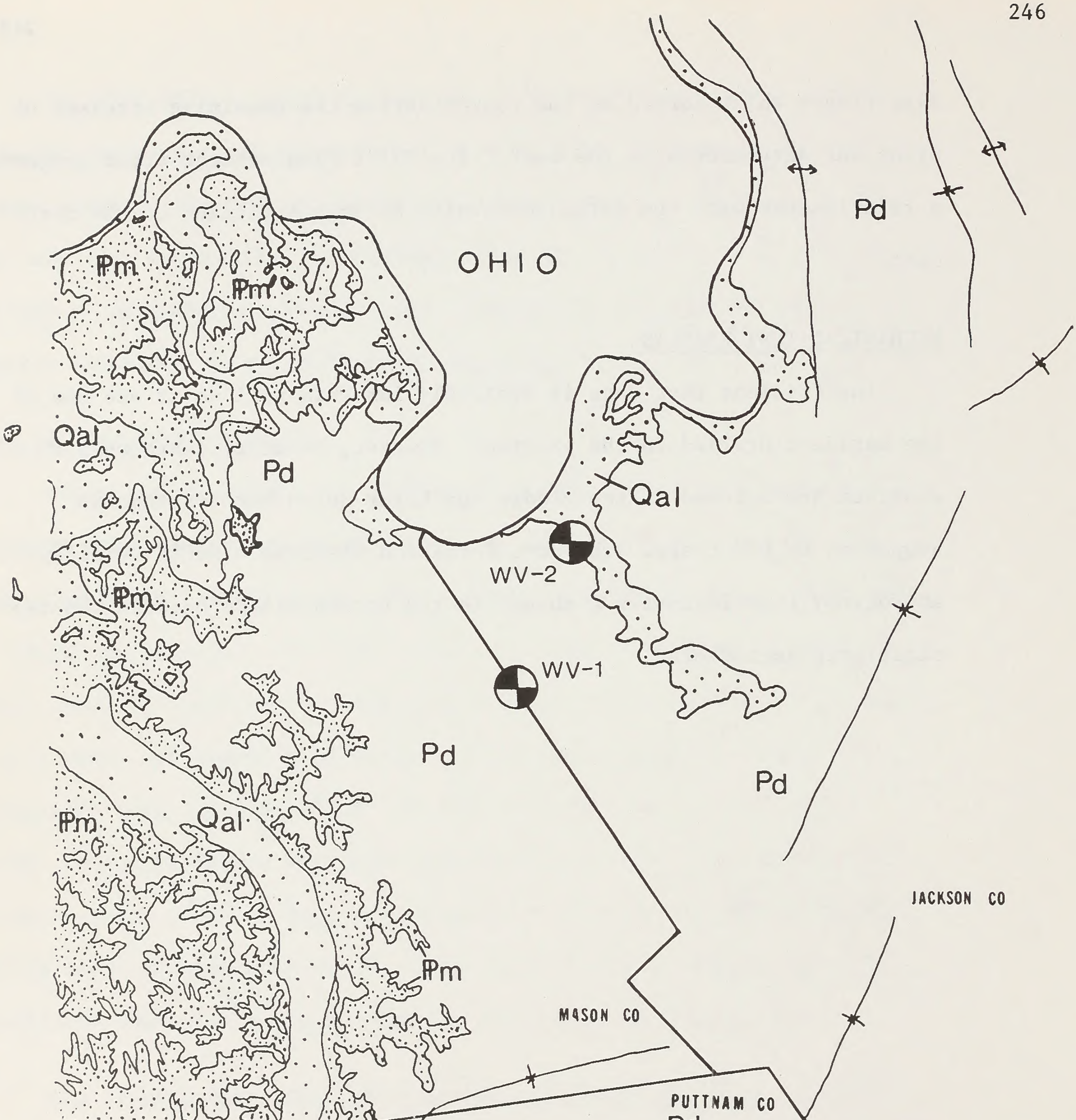
Insufficient test data is available for this well as it was one of the earliest drilled in the program. However, velocity tests show a distinct N60°W trend in the Middle and Lower Huron Members that is supported by DTS tests. The Java Formation displays a N60°E velocity anisotropy that indicates a change in the stress fields between the two stratigraphic members.

*[1] p. 68

*[2] p. 68

*[3] p. 69

*[4] p. 70.



E.G.S.P. WEST VIRGINIA-1,2 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

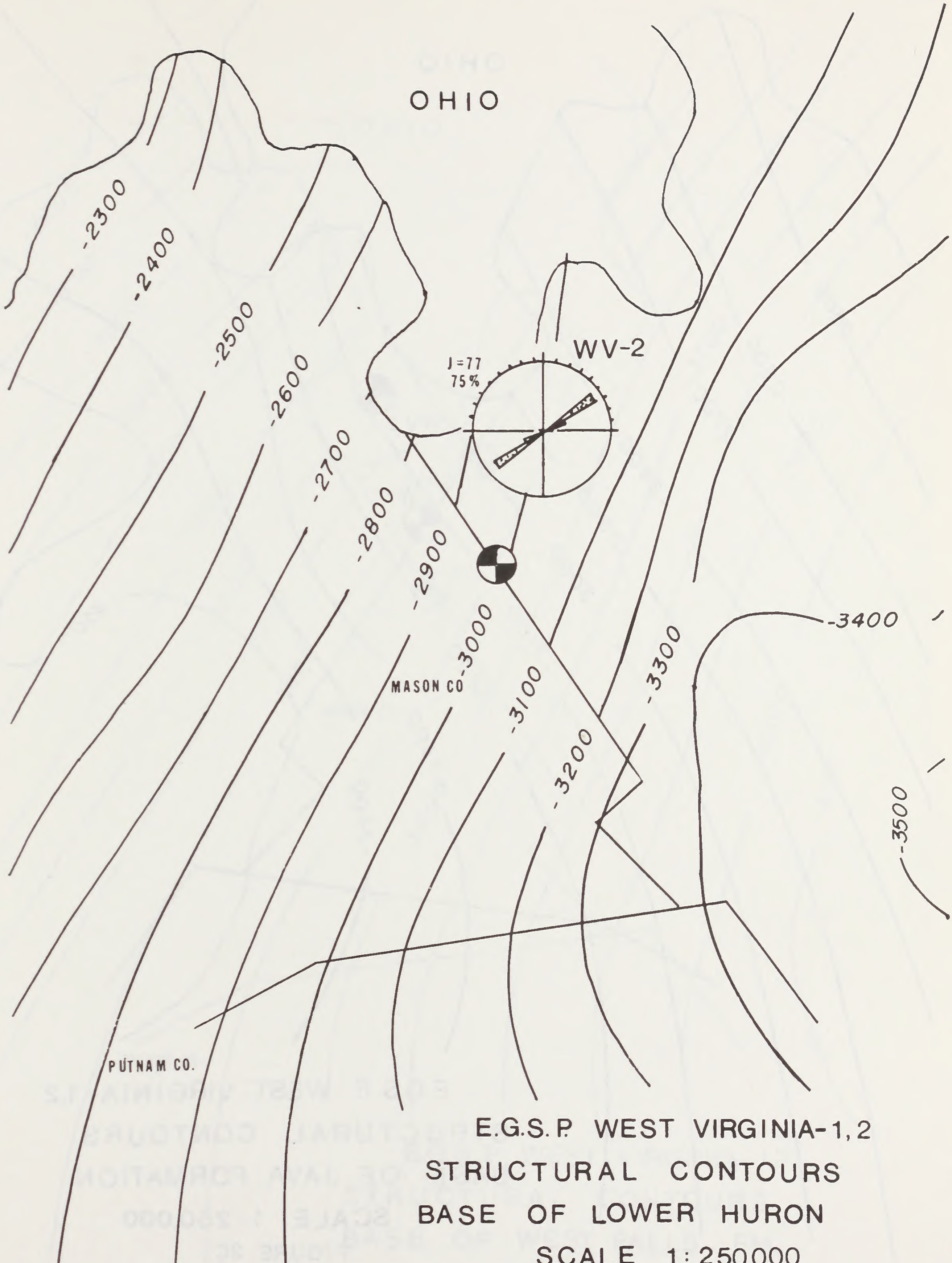
LEGEND

Qal	ALLUVIUM	Quaternary
Pd	DUNKARD Gp.	Perm. or Penn.
ℙm	MONONGAHELA Gp.	Pennsylvanian

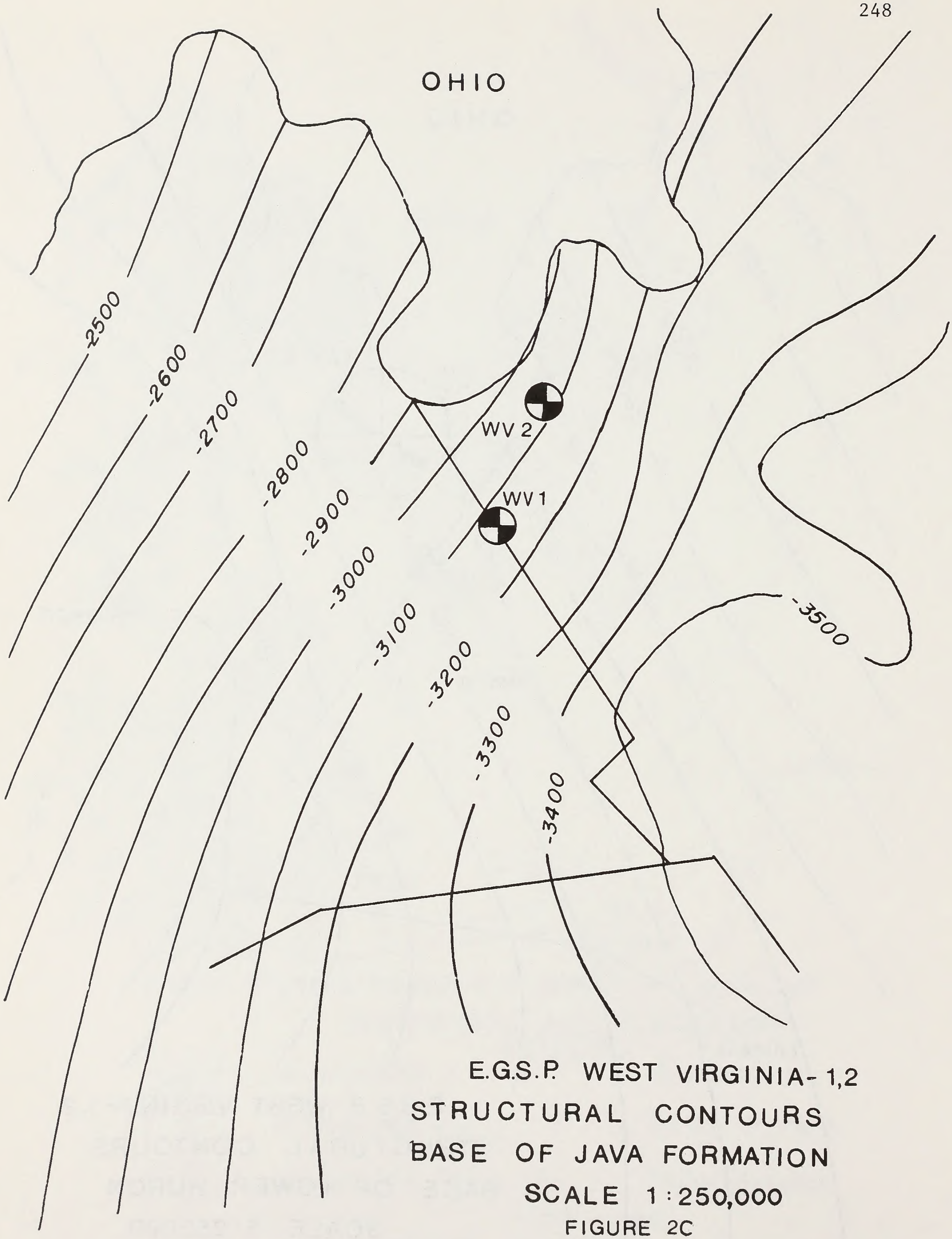
ANTICLINE SYNCLINE

SCALE 1 : 250,00

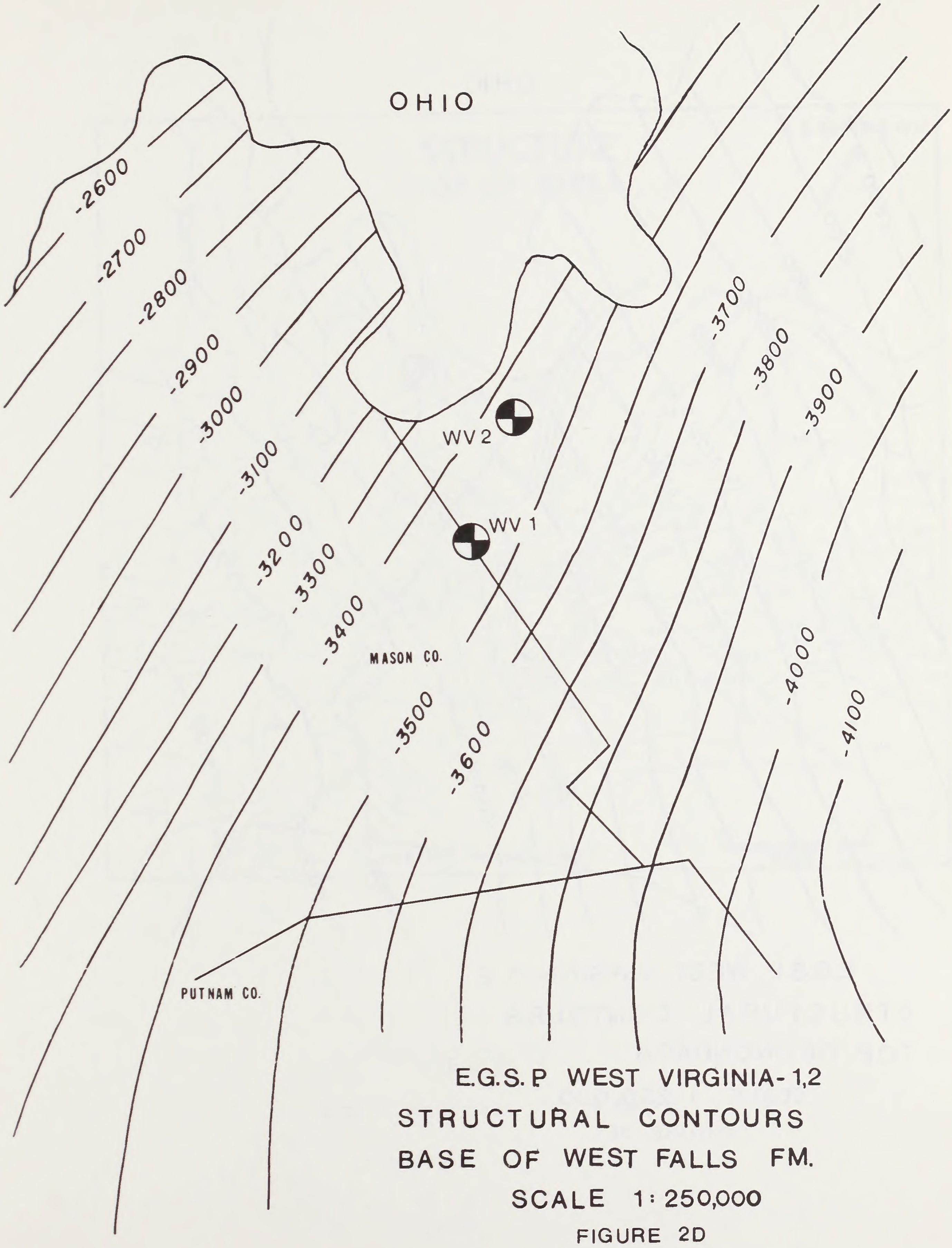
FIGURE 2A



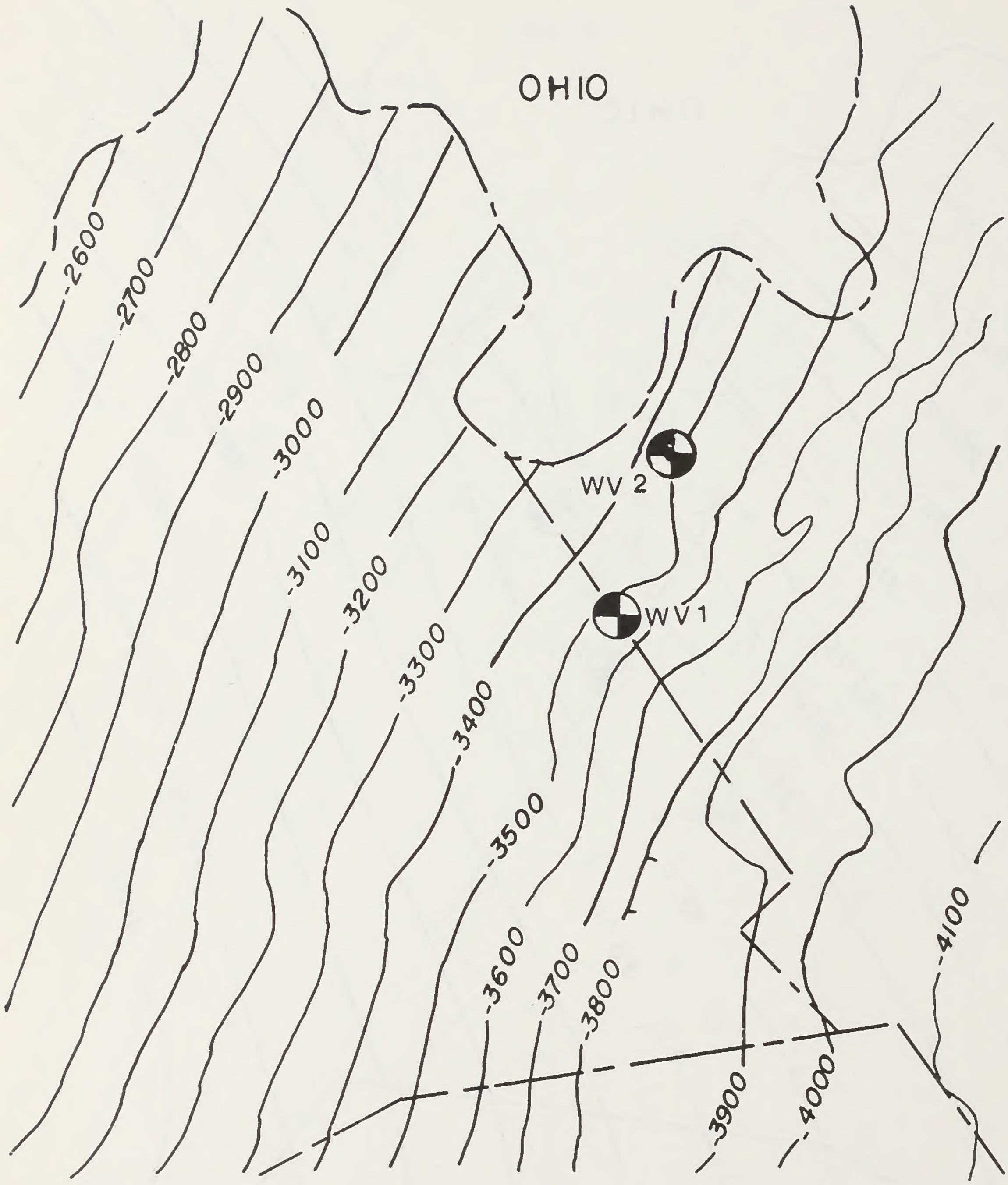
E.G.S.P. WEST VIRGINIA-1,2
STRUCTURAL CONTOURS
BASE OF LOWER HURON
SCALE 1:250000
FIGURE 2B



E.G.S.P. WEST VIRGINIA-1,2
STRUCTURAL CONTOURS
BASE OF JAVA FORMATION
SCALE 1:250,000
FIGURE 2C



E.G.S.P WEST VIRGINIA- 1,2
STRUCTURAL CONTOURS
BASE OF WEST FALLS FM.
SCALE 1: 250,000
FIGURE 2D



E.G.S.P. WEST VIRGINIA-1,2
STRUCTURAL CONTOURS
TOP OF ONONDAGA
SCALE 1:250,000
FIGURE 2E

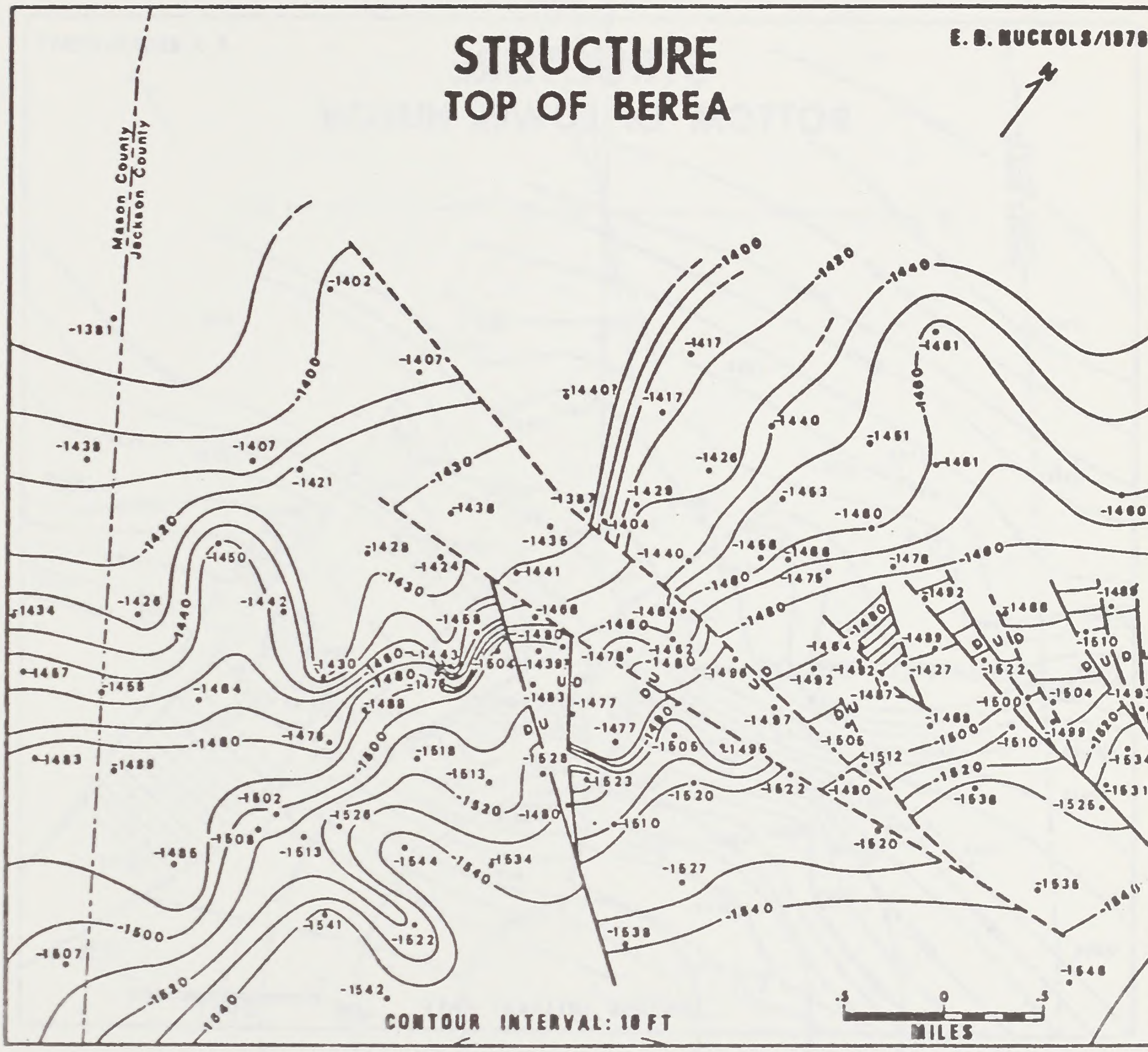


FIGURE 2F

DETAIL STRUCTURE: TOP OF BEREA

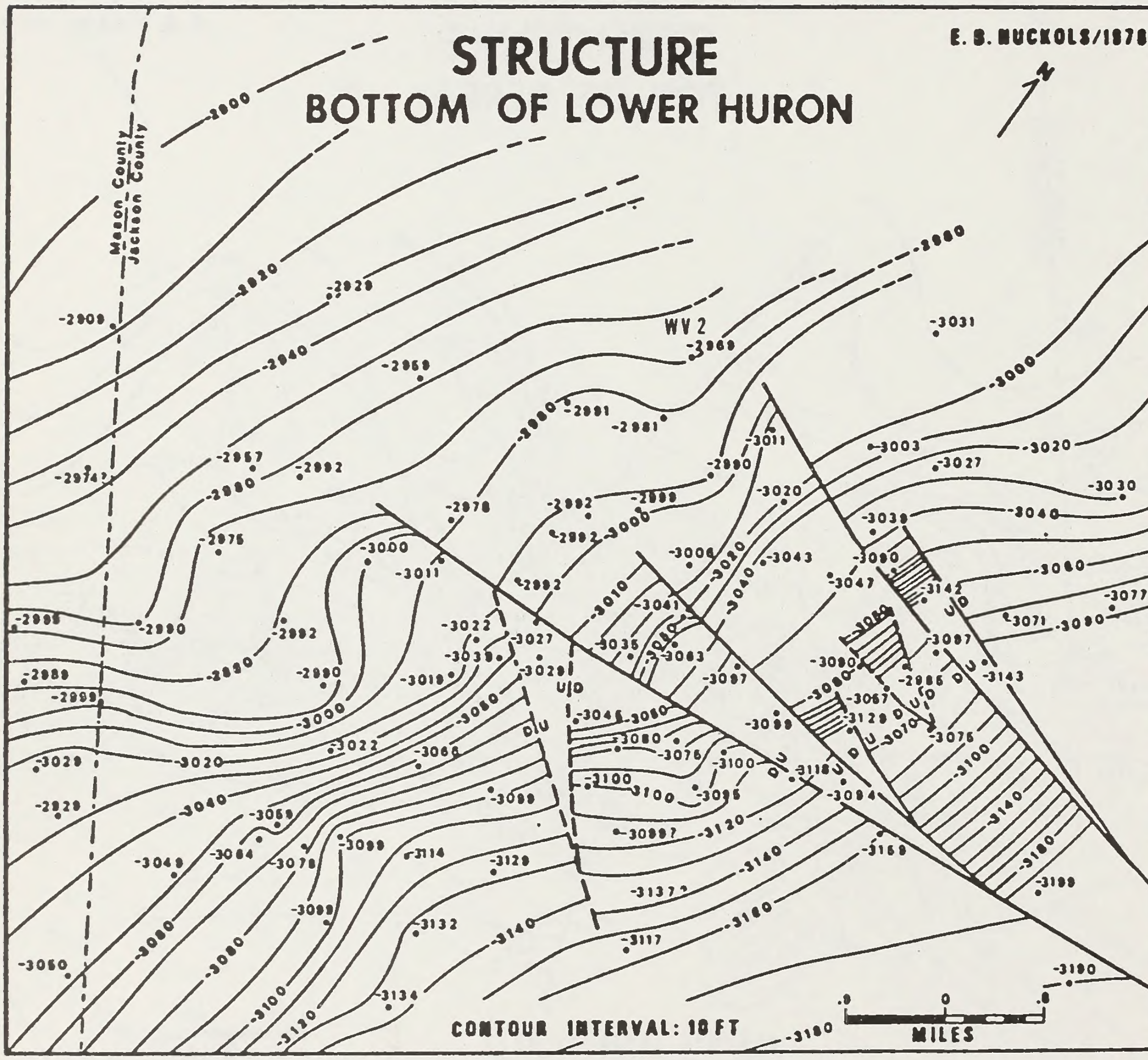
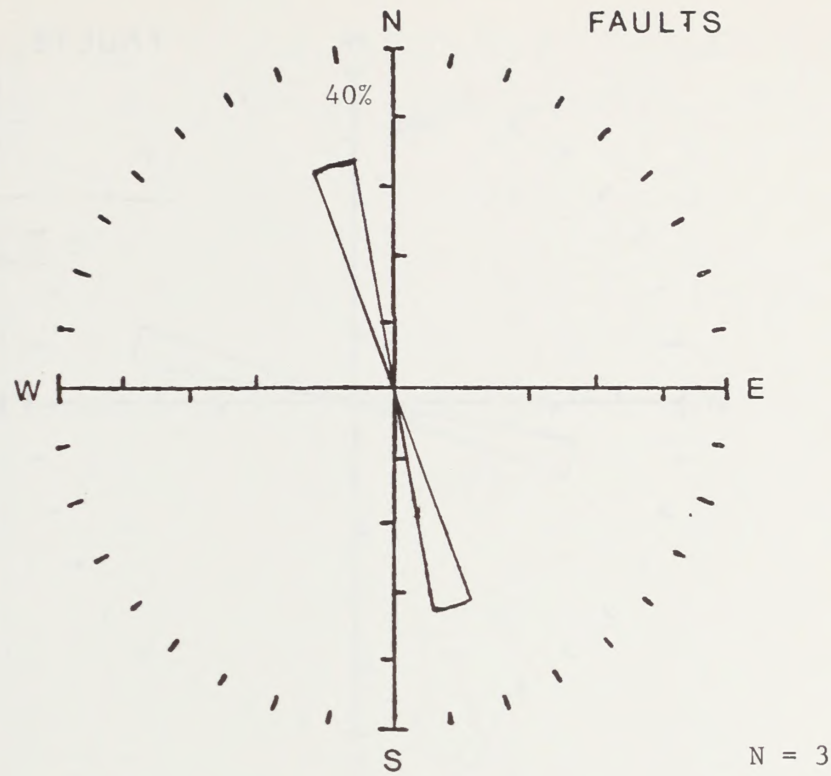
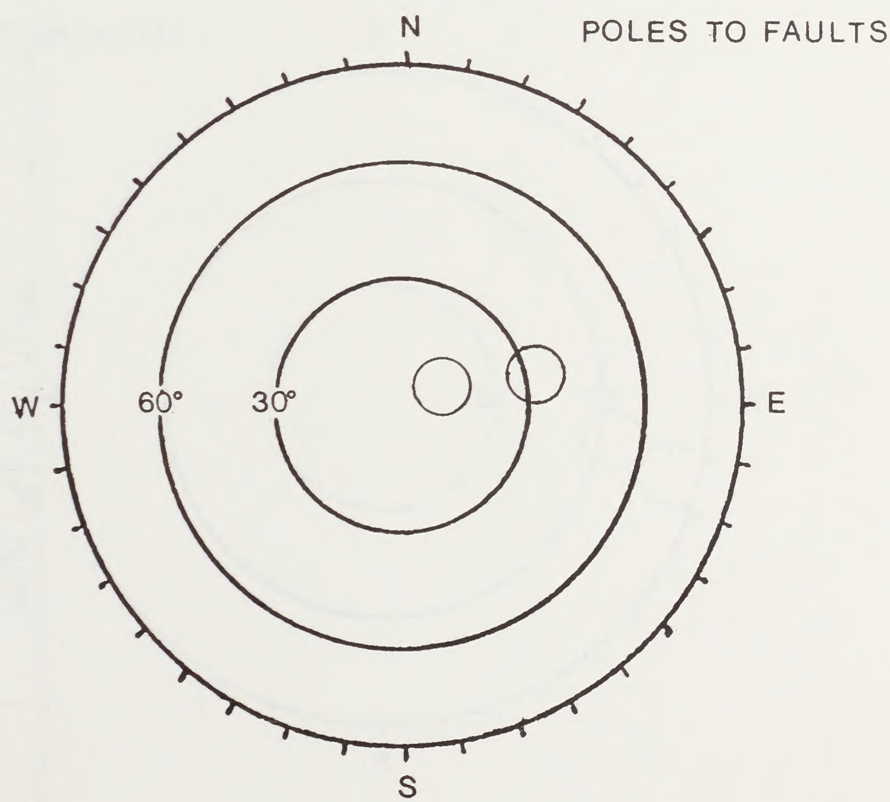


FIGURE 2G

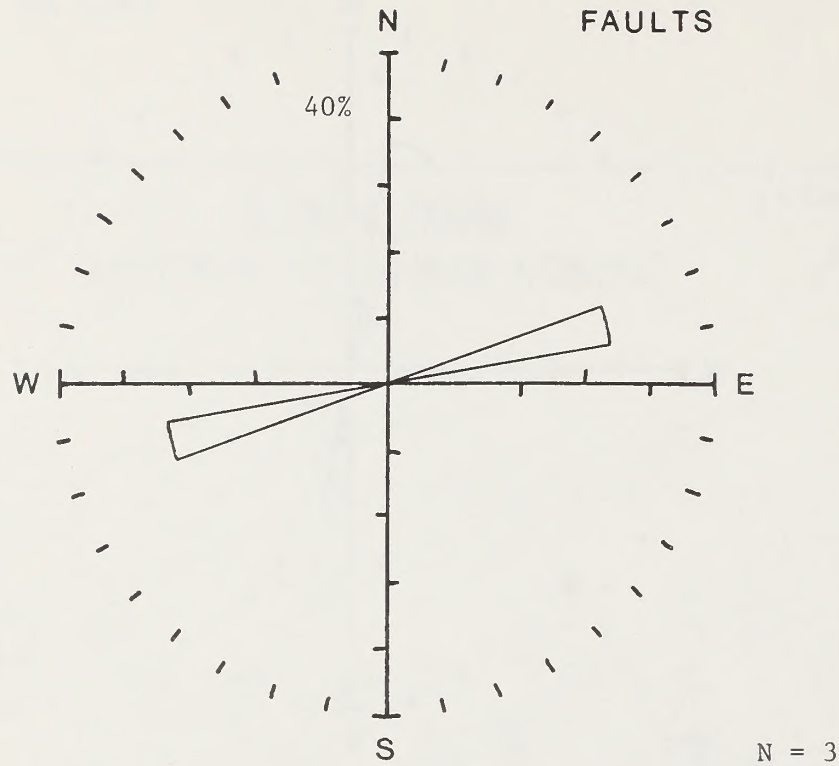
DETAIL STRUCTURE: BOTTOM OF LOWER HURON

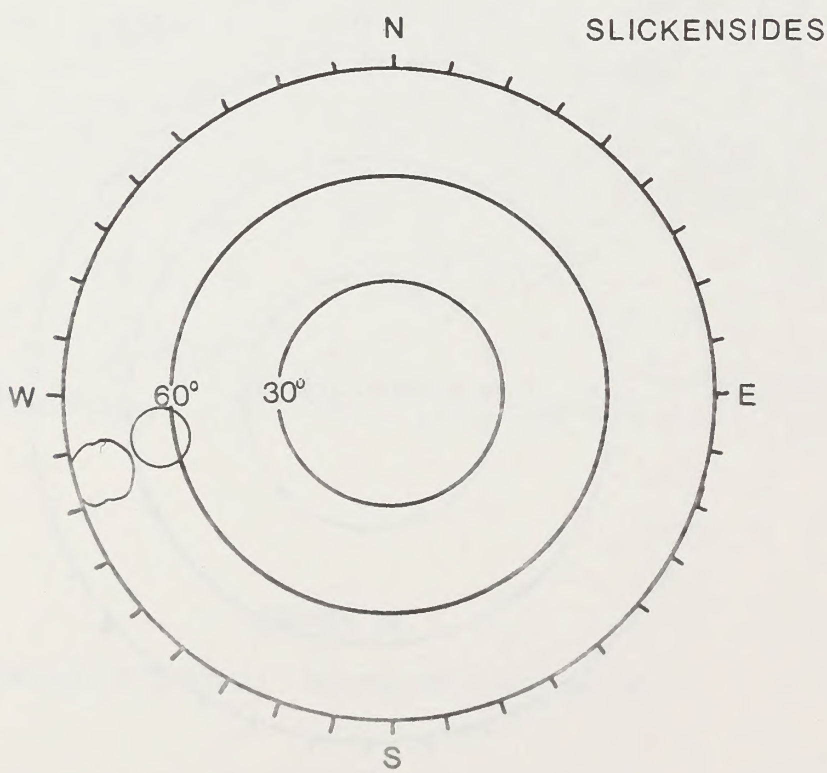




EGSP-WEST VIRGINIA #2

Figure 2H. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.





EGSP-WEST VIRGINIA #2

Figure 2I. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.

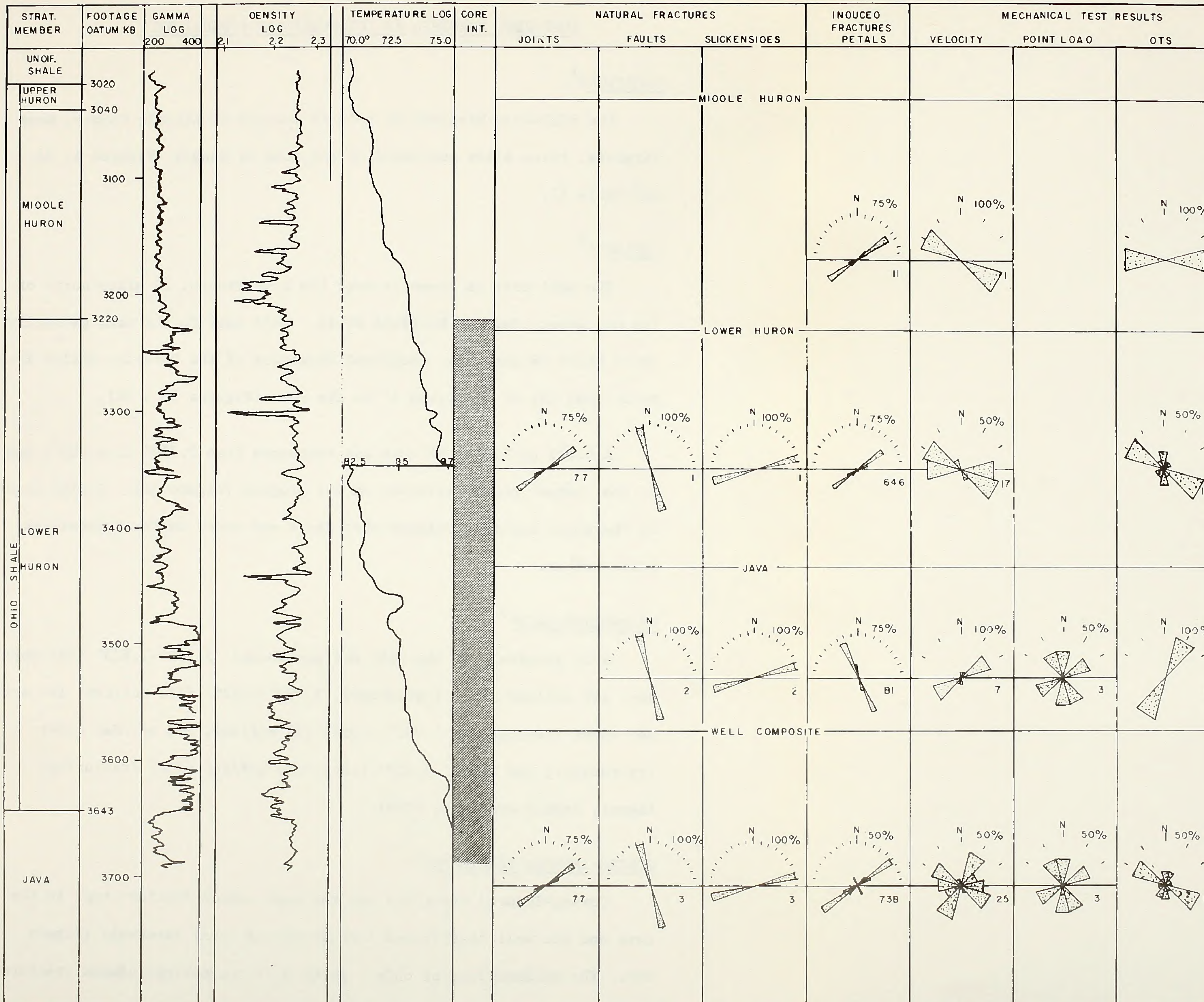


FIGURE 21 EGSP WEST VIRGINIA 2 WELL SUMMARY

CLIFFS ENGINEERING, INC. 1982
JAK

EGSP-WEST VIRGINIA #3 (COLUMBIA GAS #20403) WELL

LOCATION*[1]

The EGSP-West Virginia #3 well is located in Lincoln County, West Virginia, three miles southwest of the town of Ranger (Figures 1, 3A, and Table 1).

GEOLOGY*[2]

The well site is directly over the Rome Trough, 15 miles north of the northeast trending Warfield Fault. Fold axes in the area generally trend N65°E (Figure 3A). Regional structure of the Devonian Shales is a monoclinal dip of less than 1° to the east (Figures 3B - 3E).

A total of 1,308' of core was recovered from 2,720' to 4,025', one of the longest cores retrieved in the program (Figure 3H). Coring began in the upper Undifferentiated Ohio Shale and ended in the Rhinestreet Shale Member.

PRODUCTION DATA*[3]

Four intervals of the well had gas shows: 2,775'-2,825' (381 mcf/day, 160 mcf/day after fracturing), 2,950'-3,225' (103 mcf/day, 107 mcf/day after fracturing), 3,400'-3,650' (95 mcf/day, 200 mcf/day after fracturing), and 3,850'-4,025' (show, 110 mcf/day after fracturing) (Komar, Frohne and Yost, 1978).

CORING-INDUCED FRACTURES*[4]

Coring-induced fractures are the most common fracture type in the core and are well distributed throughout the cored intervals (Figure 3H). The orientations of only a portion of the coring-induced fractures

were measured due to the poor condition of the core. The coring induced fracture composite rose diagram (Figure 3H) has two peaks, N55°-75°E with an average strike of N65°E, and N83°E. There is an 1.0% chance that each of these peaks do not exist. Coring induced fracture strikes are consistent throughout the remainder of the hole except near the base of the Java Formation where they swing to an east-west orientation (Figure 3H). This swing may be the effect of altered stress fields due to slip planes bounding the Java Formation.

The generally consistent fracture orientations suggest that a stress or fabric anisotropy exists in the rock. This anisotropy may be related to the general east to northeast trending maximum compressive stress present in most of eastern North America (Sbar and Sykes, 1973).

NATURAL FRACTURES*[5]

Natural fractures are found throughout the core except in the Java Formation. A concentration of fractures exists in the interval 3,030'-3,070'. The natural fracture composite rose diagram (Figure 3H) has three peaks. There is a 1.0% chance that the peaks at N60°-70°W and N27°W do not exist, and a 10% chance that the peak at N83°E does not exist.

Northeast striking natural fracture sets are found throughout the core. They parallel the coring induced fracture strikes to the point of swinging from N65°E to N83°E near the base of the Lower Huron Member of the Ohio Shale and then back to N65°E at the base of the Java Formation (Figure 3H). The parallelism of natural and coring-induced fractures suggests that there may have been, and still may be, altered stress

fields in the Java Formation and that these natural fractures formed in relation to the same stresses responsible for the coring-induced fractures. The two trends also generally parallel fold axes in the area, suggesting that these fractures formed as release features when tectonic stresses were relaxed. Some of the fractures in the two northeast-striking sets are mineralized, primarily with massive or crystalline calcite.

The N27°W fracture set is vertically limited, occurring only in the interval 3,030'-3,070'. This set is mineralized exclusively with massive or crystalline dolomite or barite (Larese and Heald, 1977). This section of shale contains several inclined N75°E striking dolomite-filled fractures and is one of the gas-producing intervals of the well. The N27°W set is orthogonal to the southern Appalachian trend and probably formed as an extension fracture set under tectonic compressive stresses directed from the southeast. This mode of origin is supported by the occurrence, in this interval, of a single fault having slickensides trending N07°W, and by the inclined N75°E striking fractures which are interpreted to be mineral filled shear fractures. This fracture zone may have formed as a result of slip movement.

The difference in mineralization between the northeast-striking fractures and the northwest-striking fractures may indicate differing times of formation. Since the northeast striking sets parallel the coring-induced fractures, it seems likely that they formed later than the northwest set.

FAULTS AND SLICKENSIDES

Faults are confined to several distinct zones. One fault, as mentioned previously, is at 3,050' in the interval of N27°W striking natural fractures. Faults are also found at the base of the Lower Huron Member of the Ohio Shale (one horizontal fault), the base of the Java Formation, and throughout the entire West Falls Formation (Figure 3H). The Lower Huron and Java zones occur near viscosity boundaries, and the West Falls zone occurs in a low-viscosity dark shale unit immediately above the much stiffer Onondaga Limestone. Only the West Falls fault zone and the zone at the base of the Java Formation are vertically extensive enough to be considered decollement zones. The composite rose diagram of faults (Figure 3F) has a single statistically significant peak at N70°-85°E with an average strike of N77°E. There is a 1.0% chance that this peak does not exist. Three smaller peaks that are not statistically significant are at N75°W, N27°E, and N73°E. Poles to fault surfaces form an incomplete girdle across the equal area projection (Figure 3F). The pattern of clusters is near that expected for a shear zone, but dips of the Riedel and thrust shear clusters exceed the 30° maximum. This may be explained by rotation of the faults during shearing. The 0° dipping cluster in the center is the displacement shear cluster, the 40°NW dipping cluster is the Riedel shear cluster, and the 40°SE dipping cluster is the thrust shear cluster. R' shears may be present in the scatter in the southeast quadrant of the plot. Two small clusters corresponding to the vertical fractures of the N75°W set are found on the perimeter of the plot in the northeast and southwest quadrants. The faults of this set occur only in the Java Formation and in the Rhinestreet Member of the West Falls Formation (Figure 3H).

The composite rose diagram of slickensides (Figure 3G) has a single significant peak at N05°-20°W. There is a 1.0% chance that this peak does not exist. Two peaks which are not statistically significant occur at N27°W and N65°W. The equal area projection of slickensides (Figure 3G) has four clusters: two at 30°SE and 30°NW which result from the merging of the N05°-20°W set and the N27°W set; and two on the perimeter of the plot corresponding to the subhorizontal slickensides of the N65°W. The N05°-20°W set occurs primarily in the Angola Shale Member of the West Falls Formation. The N65°W set occurs primarily in the Rhinestreet Shale Member of the West Falls Formation and consists of nearly horizontal slickensides on the vertical N75°W striking faults. The N27°W set is found only in the Rhinestreet Member of the West Falls Formation and in the lower portion of the Java Formation. Very few slickensides in the core are mineralized. Massive calcite is the most common filling.

The N05°-20°W and N27°W trending slickensides parallel the N27°W natural fracture set and are orthogonal to the dominant fault orientation. These three fracture sets are related in that they probably formed under the same tectonic compressive stresses that existed during the formation of the southern Appalachians. The N75°W fault set, with its N65°W trending slickensides, shows no relationship to any known nearby structures.

MECHANICAL TEST RESULTS

Ultrasonic velocity tests show a primary E-W orientation and secondary N60°E trend (Figure 3H). The variation down through the stratigraphic layers indicates changes in stress from member to member. A slight but similar trend is also displayed by the point load tests (Figure 3G) with a well composite showing a strong N60°E orientation of weakness planes. The DTS samples (Figure 3H) show a random orientation which is due to the bedding plane failure problem experienced with the test on this rock.

The tests indicate a N60°E anisotropy in the shales which is normal to the trend of the slickensides and probably resulted from stress developed by the deformation that produced faulting in the Devonian Shales.

*[1] p. 86

*[2] p. 86

*[3] p. 86

*[4] p. 86

*[5] p. 87.

E.G.S.P. WEST VIRGINIA-3,4 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

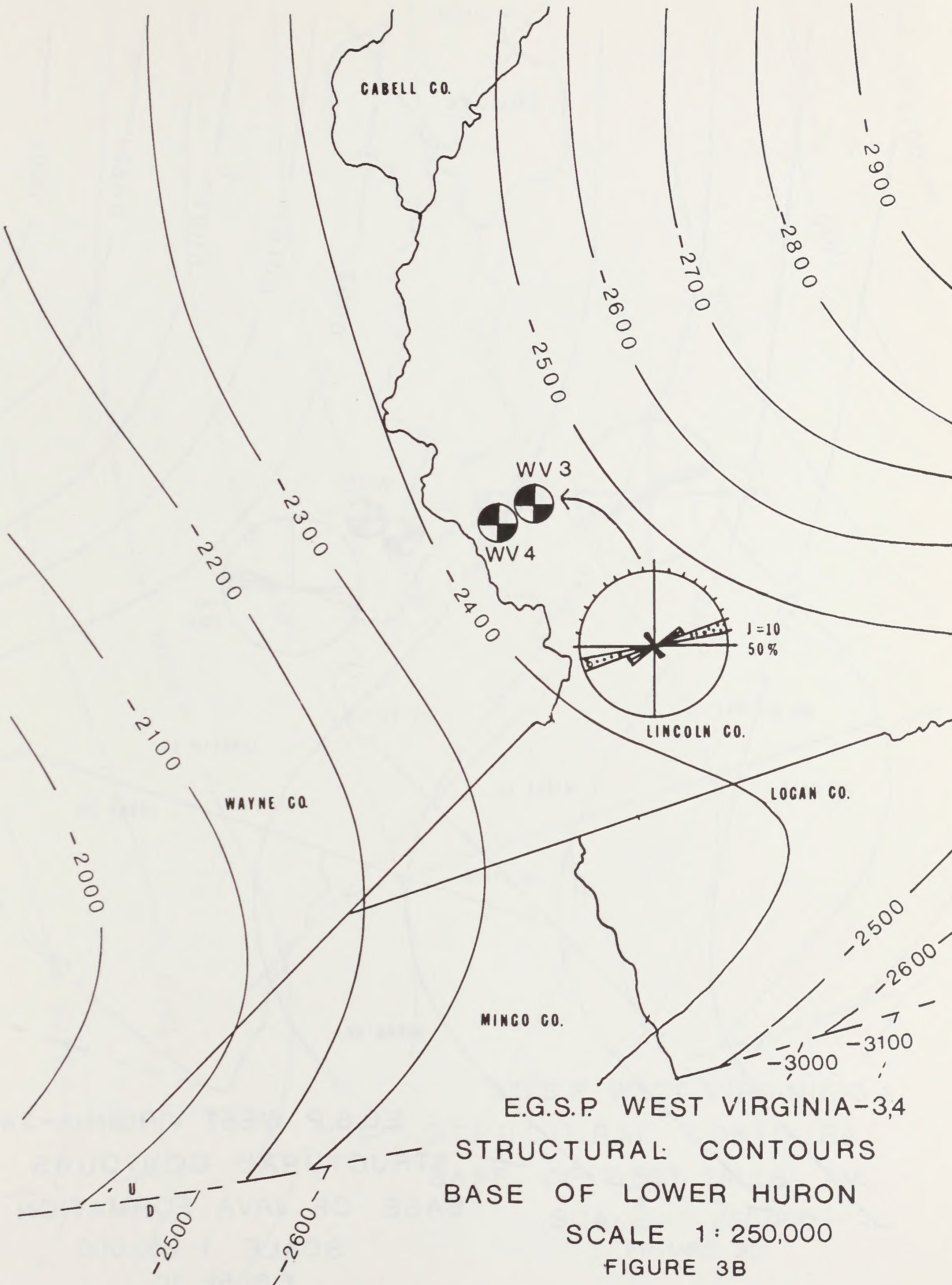
LEGEND

Pm	MONONGAHELA Gp.	
Pc	CONEMAUGH Gp.	
Pa	ALLEGHENY Fm.	Pennsylvanian
Pk	KANAWHA Fm.	

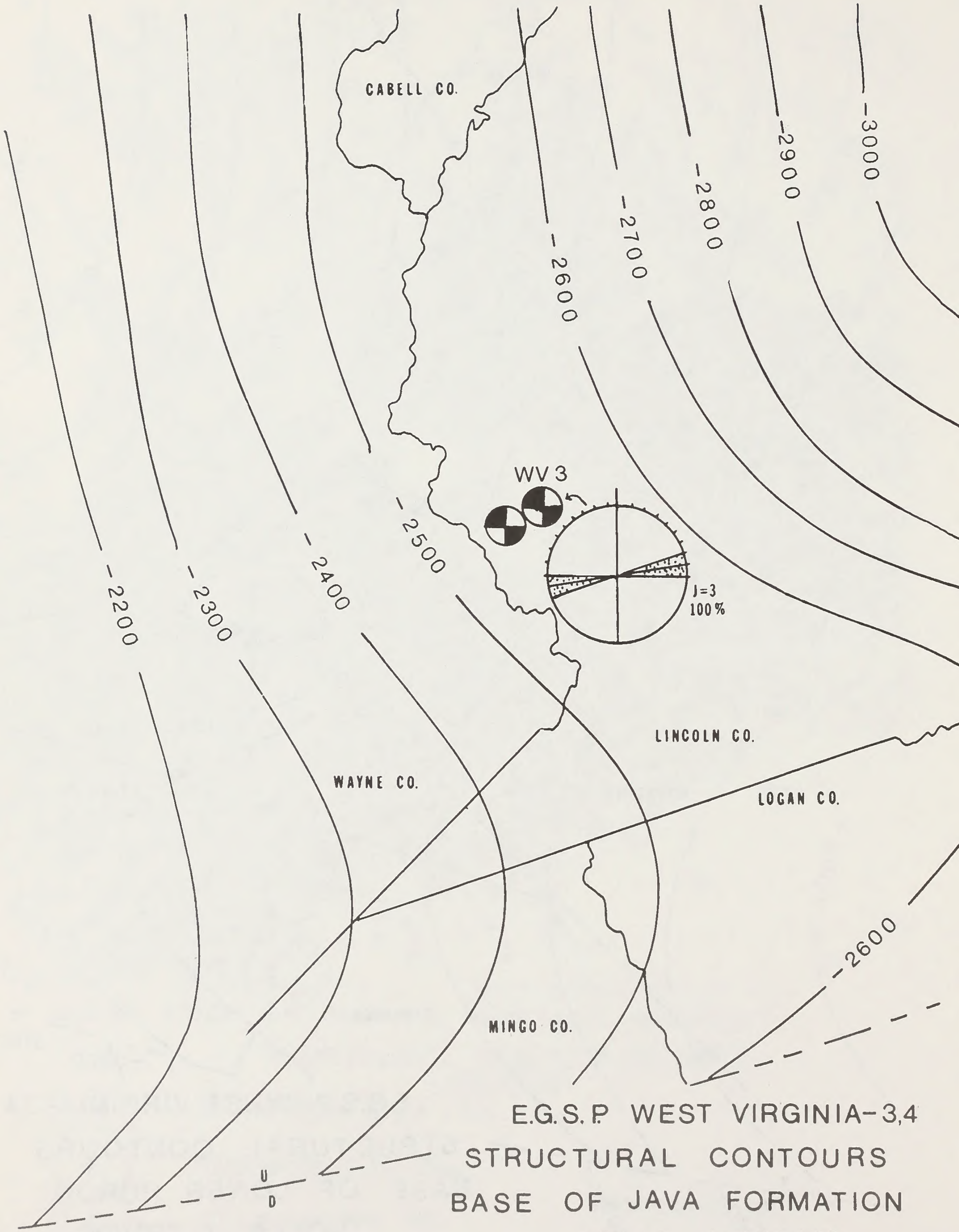
FIGURE 3A

ANTICLINE SYNCLINE

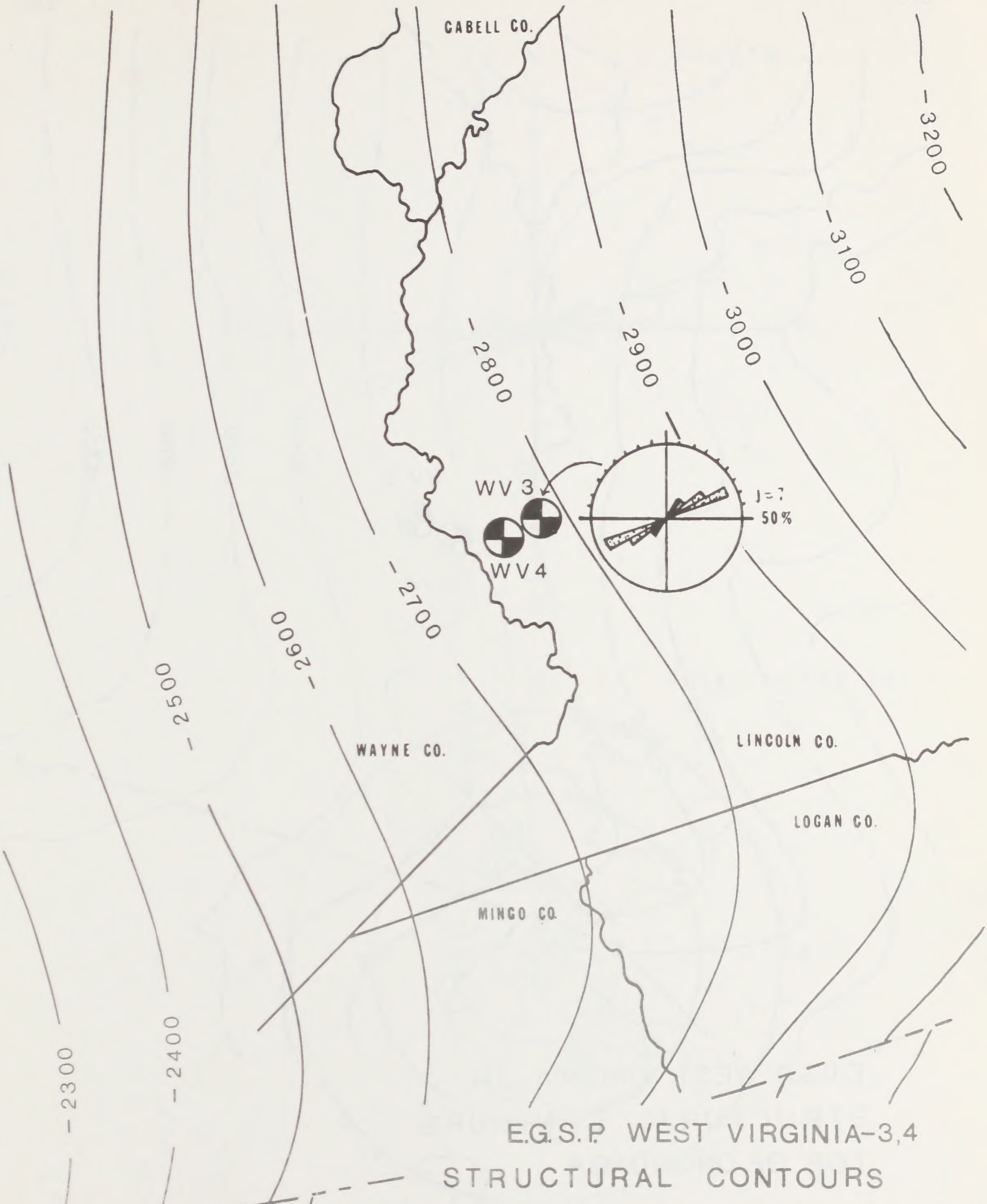
SCALE 1: 250,000



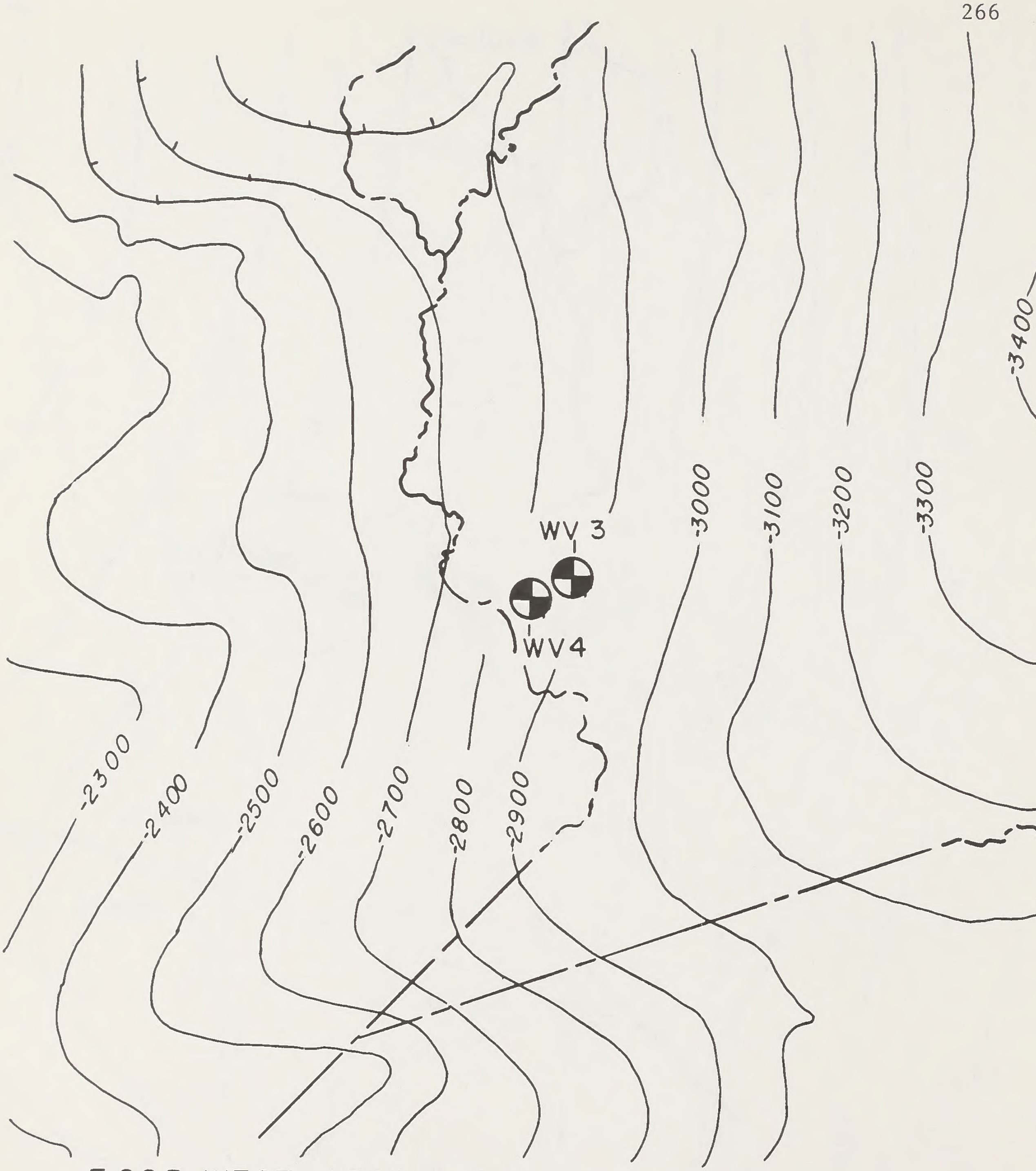
E.G.S.P. WEST VIRGINIA-3,4
STRUCTURAL CONTOURS
BASE OF LOWER HURON
SCALE 1 : 250,000
FIGURE 3B



E.G.S.P WEST VIRGINIA-3,4
STRUCTURAL CONTOURS
BASE OF JAVA FORMATION
SCALE 1:250,000
FIGURE 3C



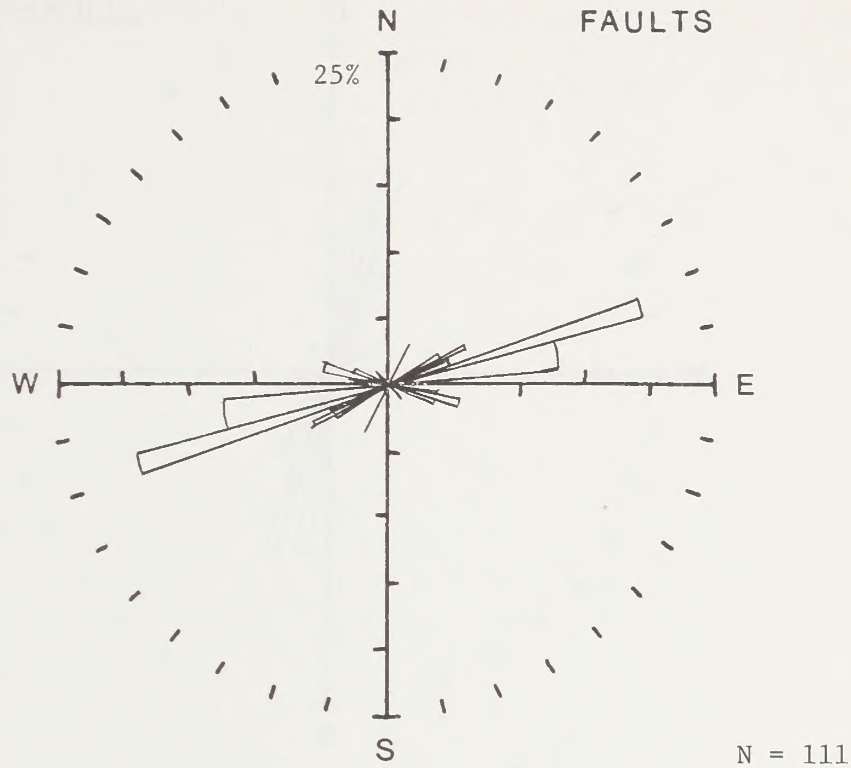
E.G.S.P. WEST VIRGINIA-3,4
STRUCTURAL CONTOURS
BASE OF WEST FALLS FM.
SCALE 1:250,000
FIGURE 3D

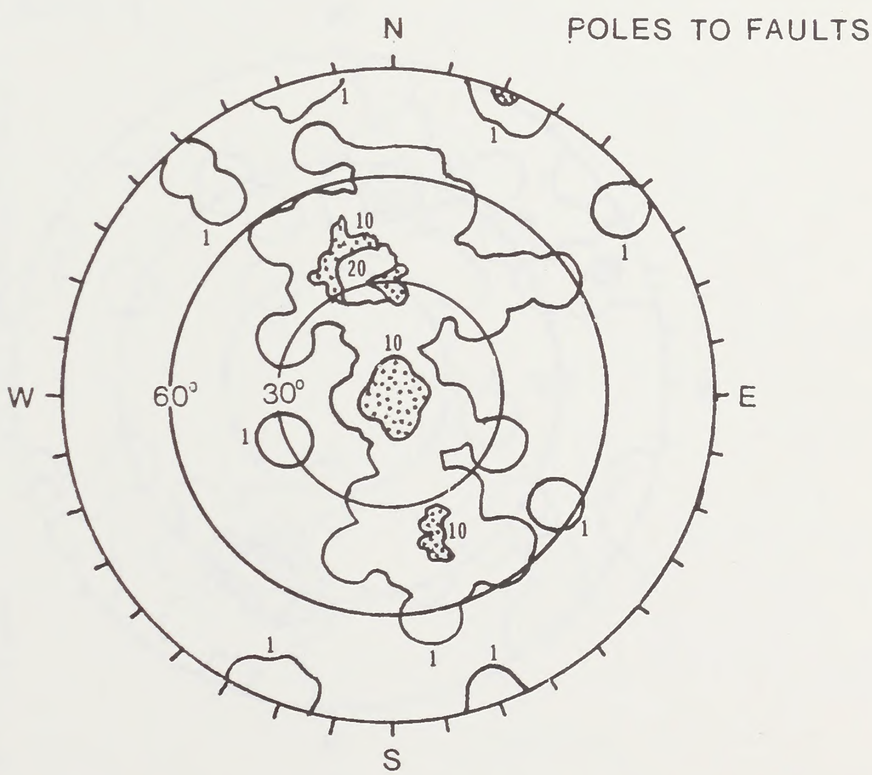


E.G.S.P. WEST VIRGINIA-3,4
STRUCTURAL CONTOURS
TOP OF ONONDAGA

SCALE 1:250,000

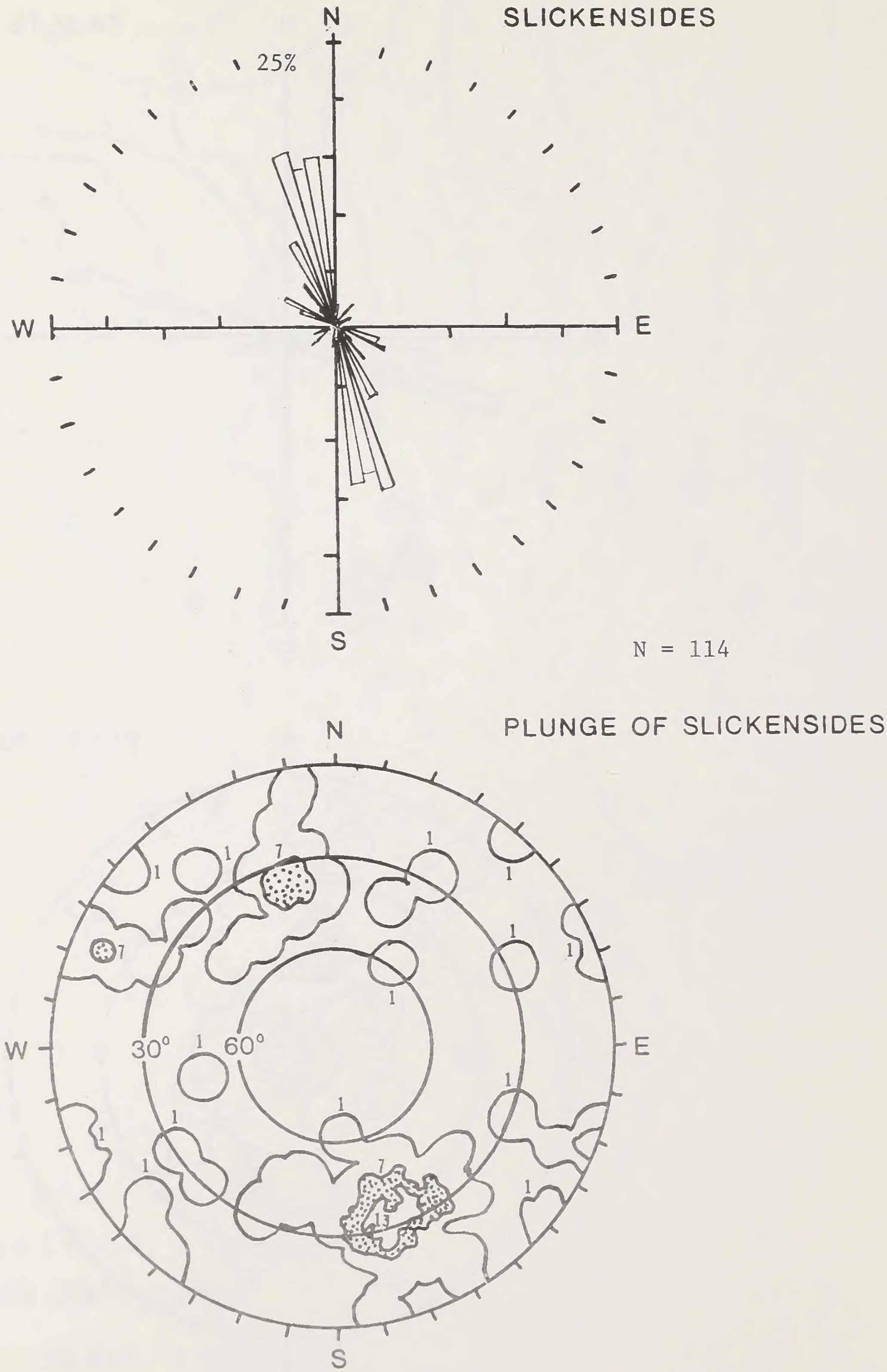
FIGURE 3E





EGSP-WEST VIRGINIA #3

Figure 3F. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.



EGSP-WEST VIRGINIA #3

Figure 3G. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.

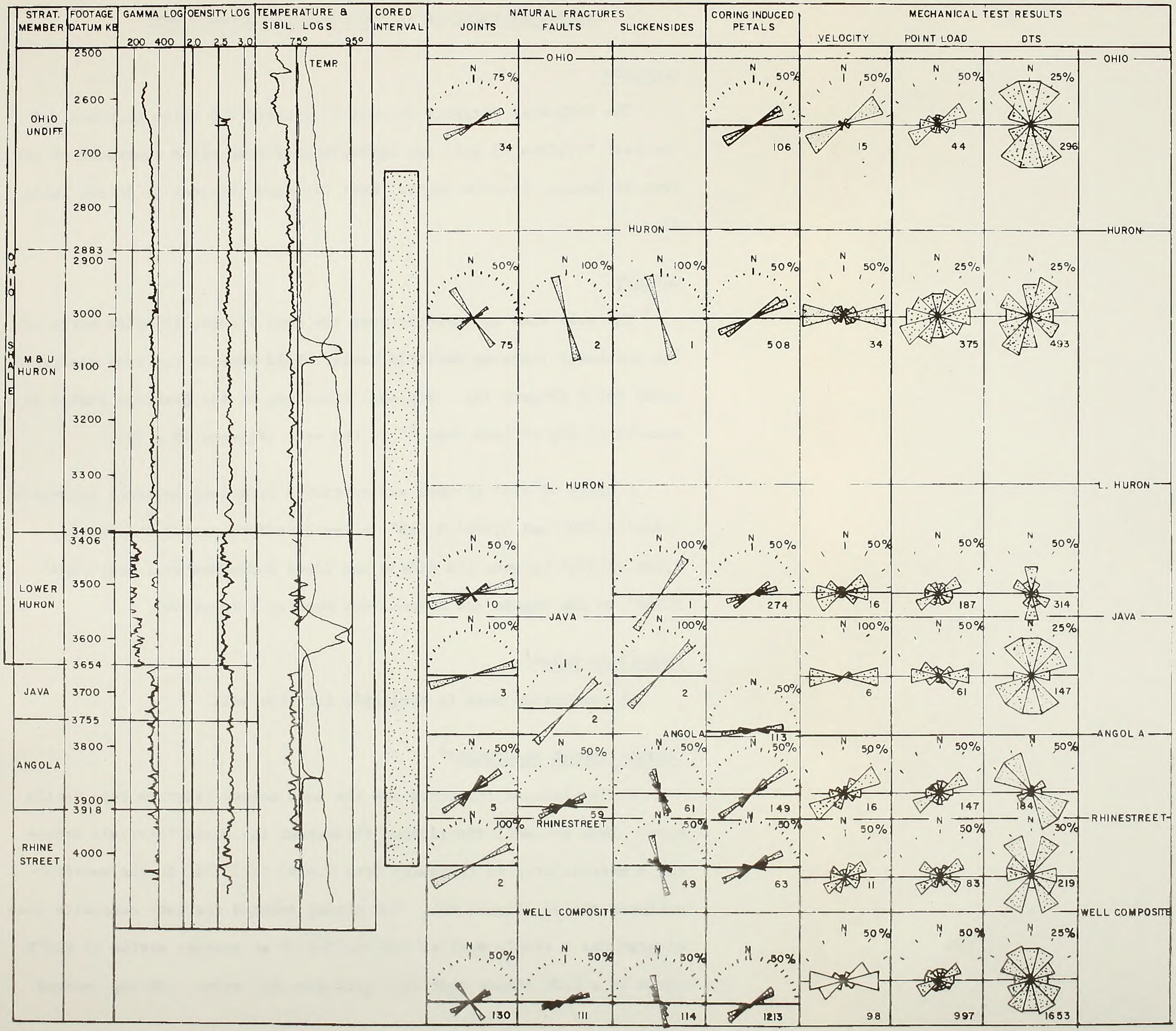


FIGURE 3H E.G.S.P. WEST VIRGINIA 3 WELL SUMMARY

CLIFFS MINERALS INC.

EGSP-WEST VIRGINIA #4 (COLUMBIA GAS #20402) WELL

LOCATION

The EGSP-West Virginia #4 well is located 0.9 miles southwest of the West Virginia #3 well and approximately four miles southwest of the town of Ranger, Lincoln County, West Virginia (Figures 1, 4A and Table 1).

GEOLOGY

The well site is directly over the Rome Trough, 15 miles north of the northeast trending Warfield Fault. Fold axes in the area generally trend N65°E (Figure 4A). Regional structure of the Devonian Shales is a monoclinal dip of less than 1° to the east (Figures 4B - 4D).

A total of 614' of core was retrieved from four separate intervals: 2,654'-2,770' and 3,000'-3,118' in the Undifferentiated Ohio Shale; 3,280'-3,588' between the Middle and Lower Huron Members; and 3,886'-3,968' in the Angola and Rhinestreet Members (Figure 4G).

PRODUCTION DATA*[1]

No production data is available for this well.

CORING-INDUCED FRACTURES*[2]

Coring-induced fractures are the most common fracture type in the core. They are well distributed throughout the cored intervals except for a notable drop in frequency from 2,654' to 2,770' in the undifferentiated shales (Figure 4G). The coring induced fracture composite rose diagram has a single peak at N20°-45°E with an average strike of N33°E. There is a 1.0% chance that this peak does not exist. Coring induced

fracture orientation distributions show only minor variations throughout the core. The greatest amount of scatter occurs in the undifferentiated shales.

The generally consistent fracture orientations suggest the presence of a stress or rock fabric anisotropy. The N33°E trending anisotropy may be related to the general east to northeast maximum compressive stress present in most of eastern North America (Sbar and Sykes, 1973). This trend is 30° more northerly than the dominant coring induced fracture trend in the nearby West Virginia #3 core well.

NATURAL FRACTURES*[3]

Natural fractures occur throughout the cored intervals. A concentration of joints is found in the interval 2,723'-2,733'. The joint composite rose diagram (Figure 4G) has a single statistically significant peak at N20°-30°E with an average strike of N27°E. There is a 1.0% chance that this peak does not exist. Two peaks that are not statistically significant occur at N60°-70°W and N60°-70°E. Several of the joint sets are mineralized, generally with massive or crystalline calcite. A greater proportion of joints are mineralized in the West Falls Formation than in any other unit in the core.

The N20°-30°E joint set parallels the coring-induced fractures and may have formed under the same stress conditions. The set also parallels the central Appalachian trend and may have formed as a release fracture set when Alleghenian tectonic stresses were relaxed. The N60°-70°E set parallels the southern Appalachian trend and also may have formed when tectonic stresses were relaxed. This set also parallels the coring-

induced fractures, natural fractures, and slickensides in the West Virginia #3 core. The N60°-70°W set is orthogonal to the central Appalachian trend and probably formed as extension fractures when tectonic compressive stresses were oriented N60°-70°W during Alleghenian deformation. The remaining joints may actually be part of the same set. They are nearly orthogonal to the southern Appalachian trend and also probably formed as extension fractures. These two sets are subparallel to the N30°-40°W joint set in the West Virginia #3 core.

FAULTS AND SLICKENSIDES*[4]

Faults are found in three zones: at 3,400' in the Middle Huron Member of the Ohio Shale; at 3,582', 10' above the base of the Lower Huron Member of the Ohio Shale; and throughout the entire cored portion of the West Falls Formation (Figure 4H). The Lower Huron zone is a soft dark shale unit immediately above the contact with the stiffer shales of the Java Formation. The West Falls zone is a low-viscosity dark shale unit immediately above the much stiffer Onondaga Limestone. Only the West Falls zone is vertically extensive enough to be classified as a décollement zone. The Lower Huron zone correlates with a similar zone in the West Virginia #3 core.

The fault composite rose diagram (Figure 4F) has a single peak at N35°-45°E with an average strike of N40°E. There is a 1.0% chance that the peak does not exist. A smaller peak which is not statistically significant occurs at N50°-60°W. The fault surfaces in this set are gouged and intensely slickensided, more so than the dominant set. Also, this set only occurs in the West Falls Formation. The poles to fault

plane surfaces form an incomplete girdle across the equal area projection (Figure 4F). The cluster pattern follows that expected for a shear zone. The 0° dipping cluster in the center is the displacement shear cluster, the Riedel shear cluster dips 20°NW, and the thrust shear cluster dips 30°SE. R' shears are not present in this core. A 50°SW dipping cluster results from the N55°W fault slickenside set. Very few of the faults in this core are mineralized, and those occur only in the West Falls Formation. Massive calcite is the dominant filling. Fault orientations show very little scatter or systematic variation with depth or stratigraphy (Figure 4H).

The slickenside composite rose diagram (Figure 4F) has a single statistically significant peak at N40°-50°W. There is a 1.0% chance that this peak does not exist. A smaller peak, at N30°-40°E, is not statistically significant. This orientation is found only on the N50°-60°W slickenside set. The equal area projection of slickensides (Figure 4G) has three clusters: two of which correspond to the low dipping N40°-50°W trending slickensides and a 50°SW dipping cluster resulting from the N33°E trending set. Slickensides show very little variation from a northwest trend, except in the Lower Huron Member of the Ohio Shale and West Falls Formation.

The N40°-50°W slickensides are subparallel to the N60°-70°W natural fractures and are orthogonal to the N35°-45°E slickenside set. These three trends are related in that they all probably formed under the same tectonic compressive stresses. The N50°-60°W slickenside set may indicate a splay off a basement fault, or compaction and settling of the

shales resulting from basin subsidence or movement along a Rome Trough Fault.

MECHANICAL TEST RESULTS

Only point load tests and DTS tests were run on the West Virginia #3 core. The point load test results show a definite N30°E anisotropy or rock fabric (Figure 4H) that parallels the joint strikes and coring induced fracture orientations. The DTS tests are random due to test problems with bedding plane separation.

The parallelism of the coring-induced fractures, the joint trends and the rock fabric indicated by testing is in disagreement with the stresses expected from the fault movement if it were compressional. The slickenside trend (Figure 4H) indicates a SE to NW movement which would develop joints parallel to that trend. If the movement were NW to SE due to subsidence in the basin, then the joints would develop normal to the movement due to tensional stresses as might be the case for this well. It is also possible that the data represents two stages of deformation, one compressive and one tensional.

*[1] p. 107

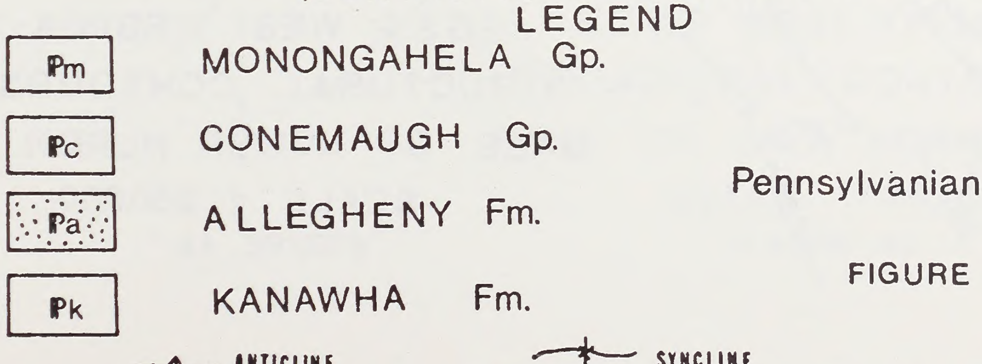
*[2] p. 107

*[3] p. 108

*[4] p. 109.

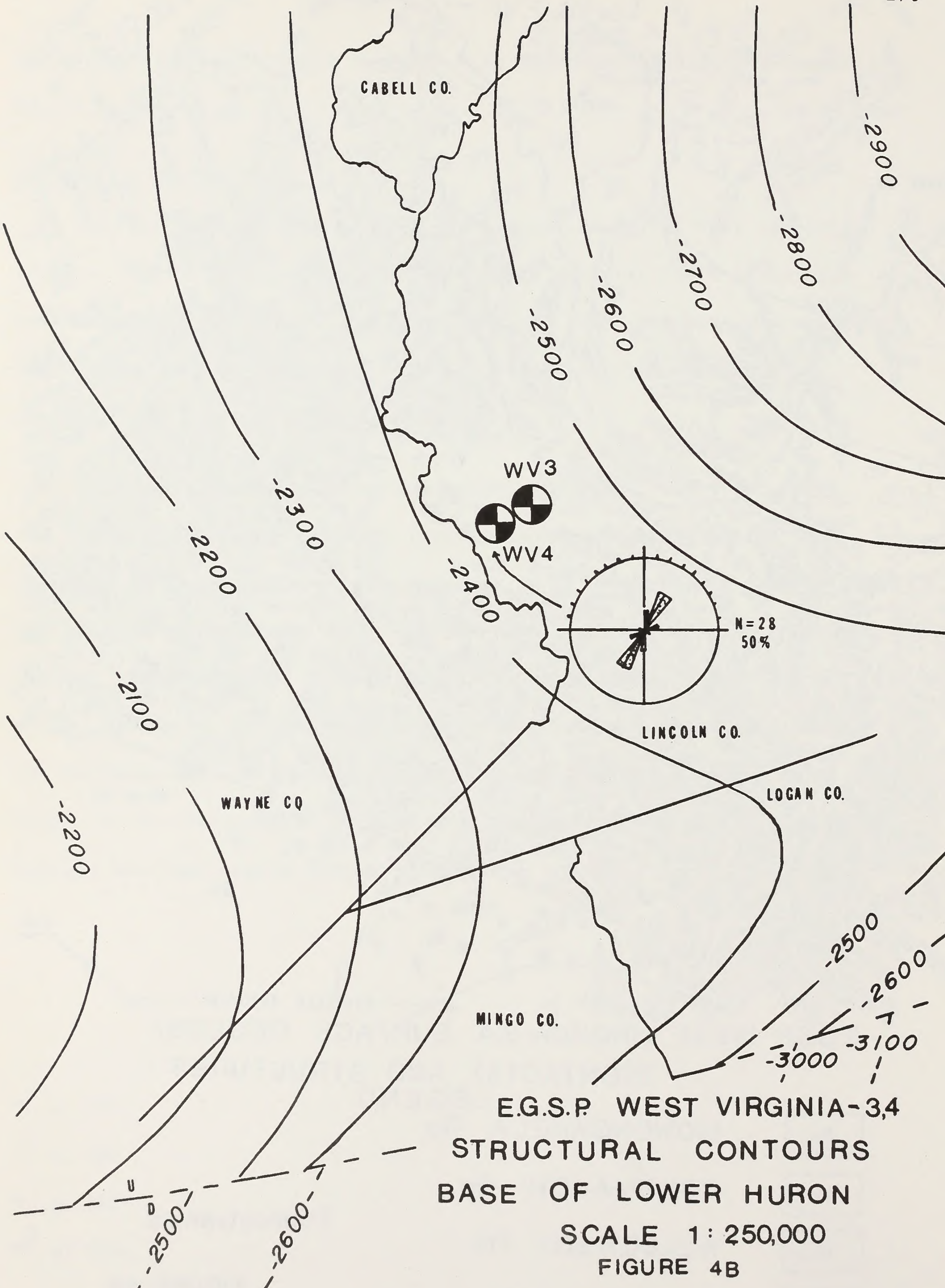
E.G.S.P. WEST VIRGINIA-3,4 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

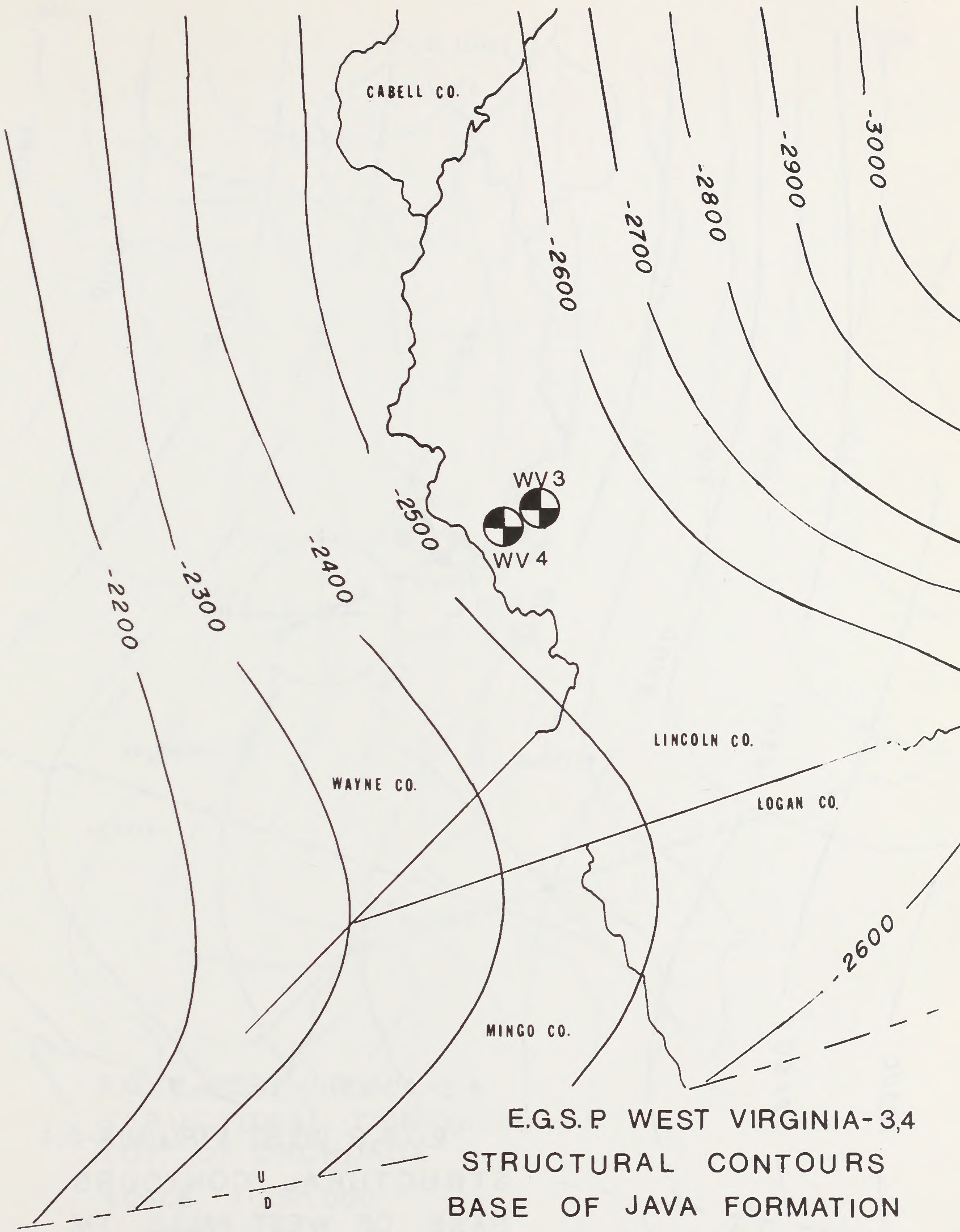


SCALE 1: 250,000

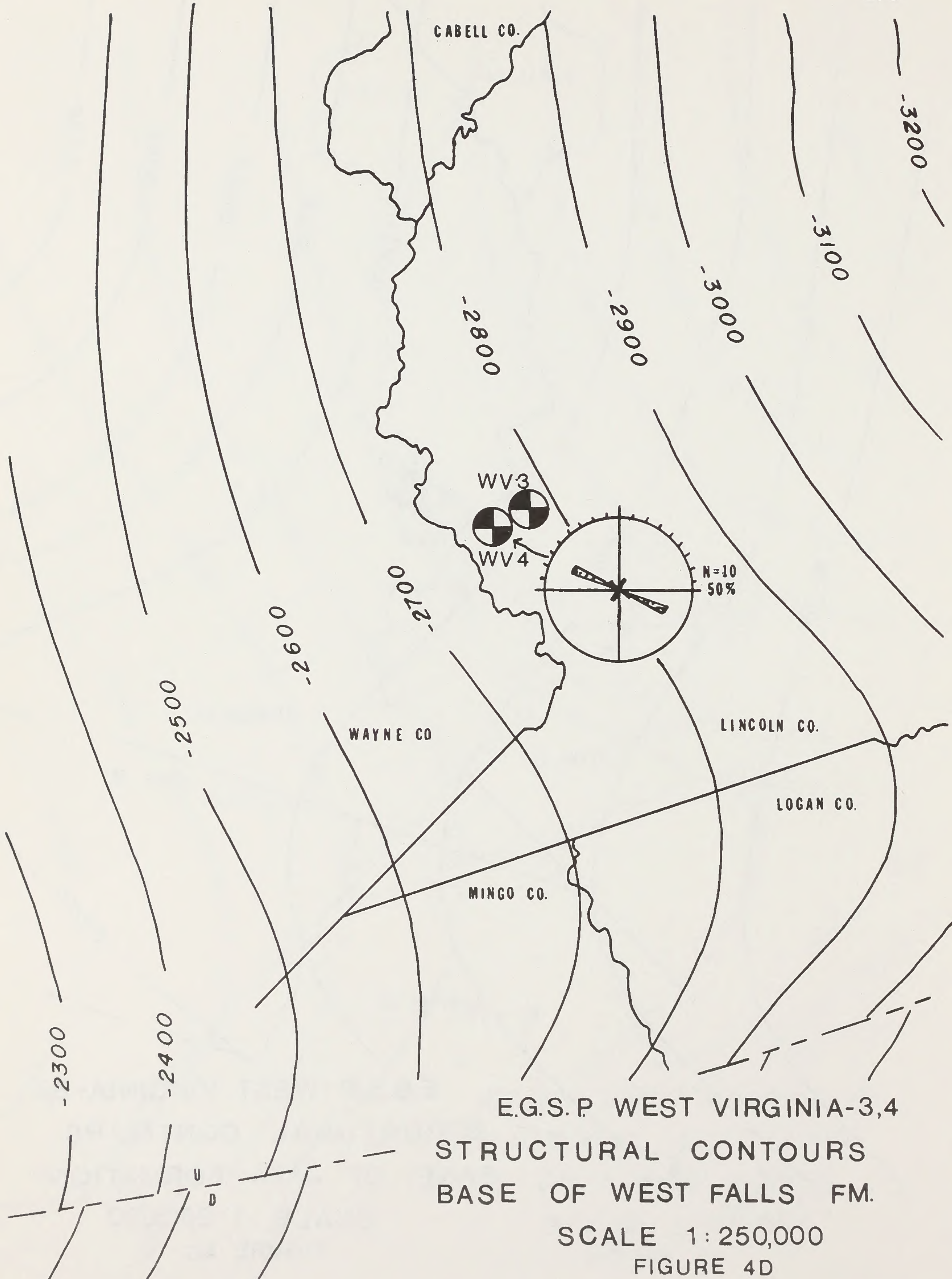
FIGURE 4A



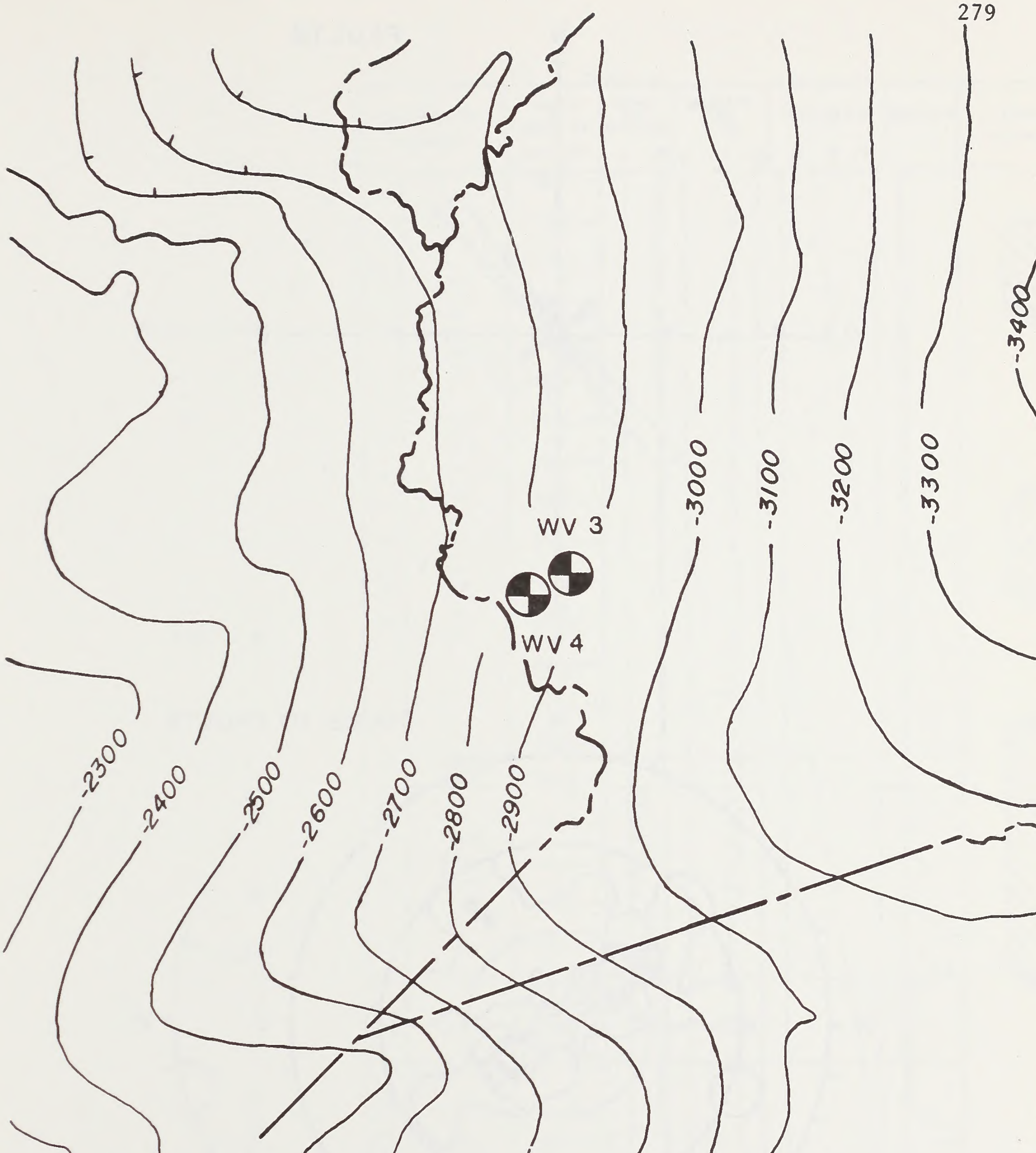
E.G.S.P. WEST VIRGINIA-3,4
STRUCTURAL CONTOURS
BASE OF LOWER HURON
SCALE 1: 250,000
FIGURE 4B



E.G.S.P WEST VIRGINIA-3,4
STRUCTURAL CONTOURS
BASE OF JAVA FORMATION
SCALE 1:250,000
FIGURE 4C



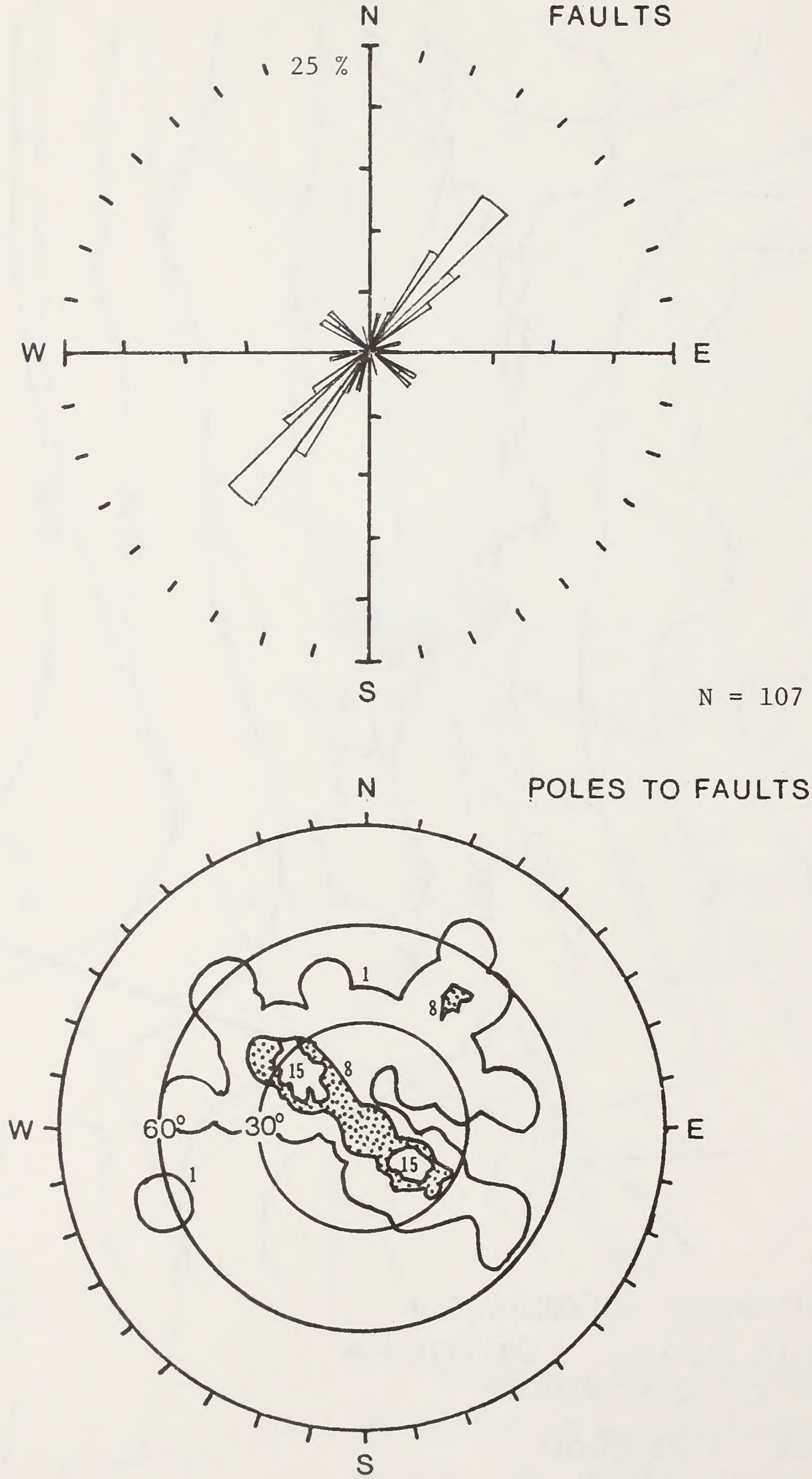
E.G.S.P. WEST VIRGINIA-3,4
STRUCTURAL CONTOURS
BASE OF WEST FALLS FM.
SCALE 1:250,000
FIGURE 4D



E.G.S.P. WEST VIRGINIA - 3,4
STRUCTURAL CONTOURS
TOP OF ONONDAGA

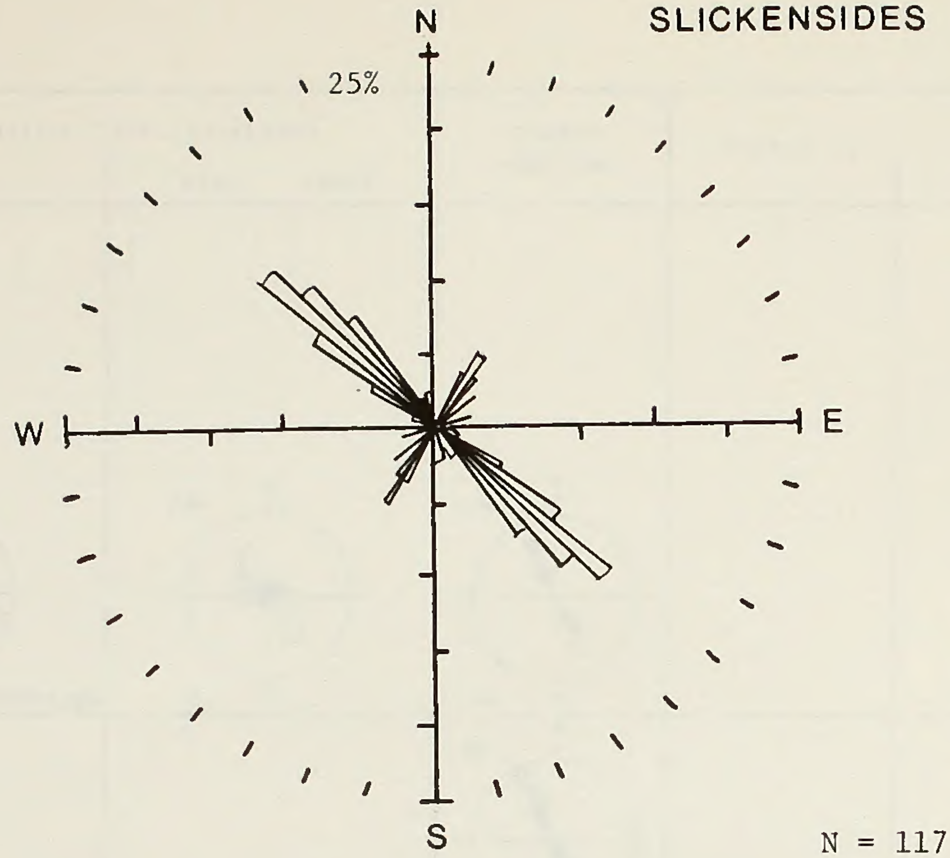
SCALE 1:250,000

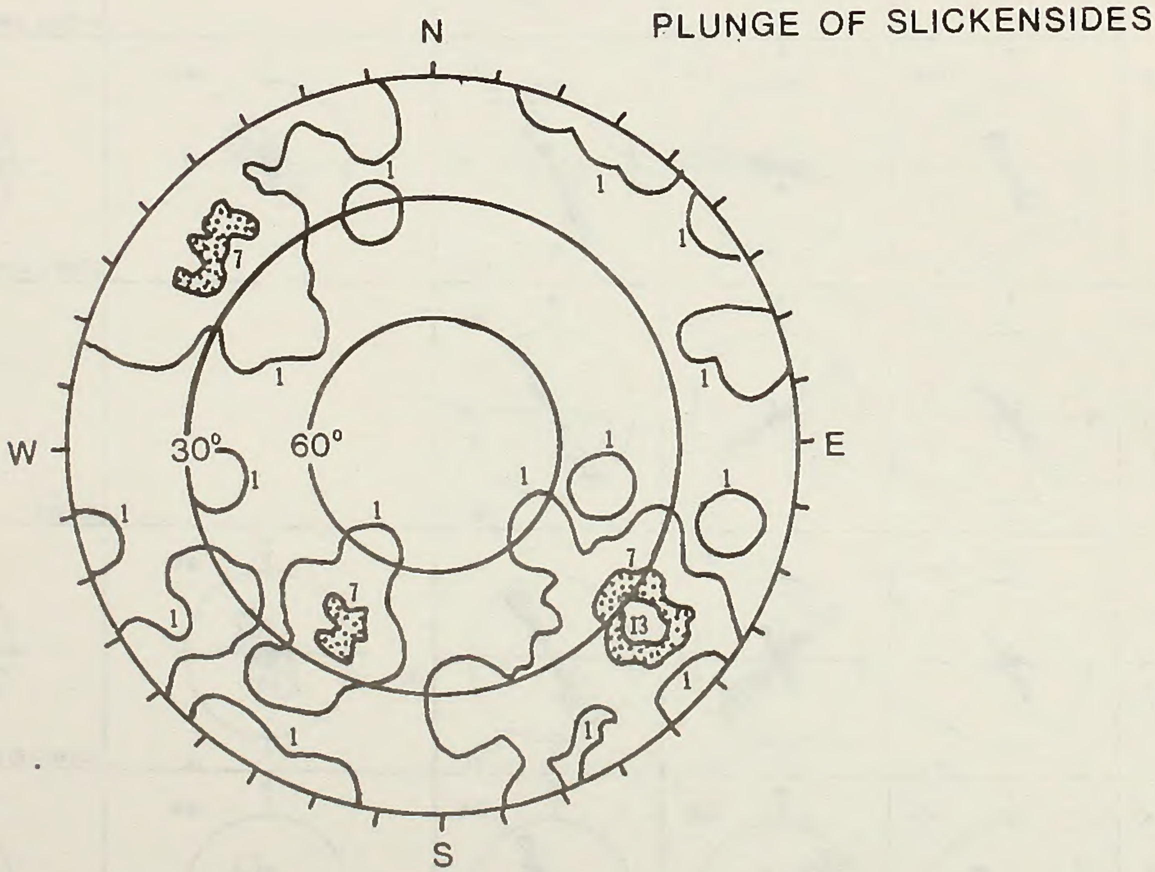
FIGURE 4E



EGSP-WEST VIRGINIA #4

Figure 4F. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.





EGSP-WEST VIRGINIA #4

Figure 4G. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.

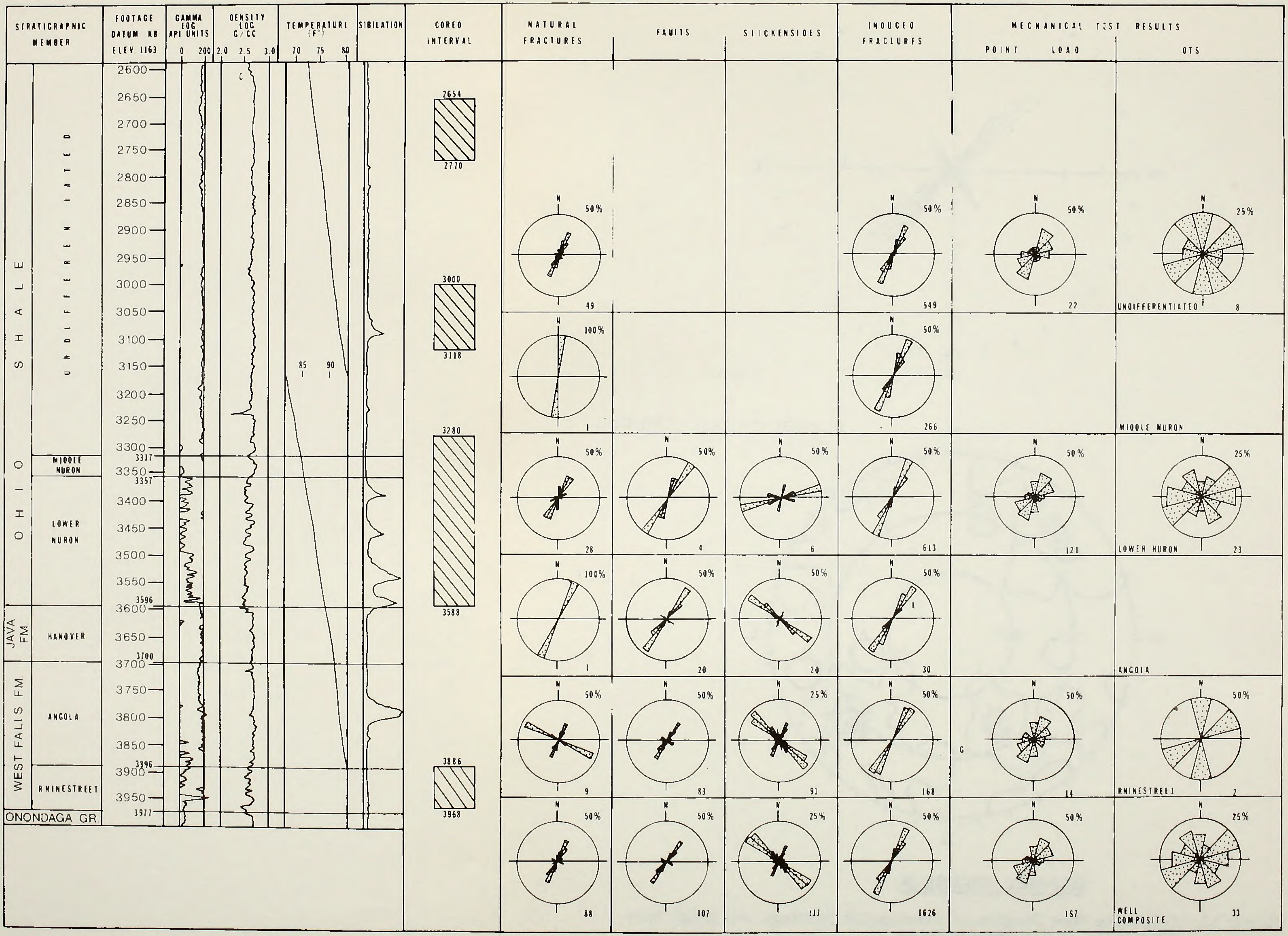


FIGURE 4N EGSP WEST VIRGINIA #4

EGSP-WEST VIRGINIA #5 (#3 D/K) WELL

LOCATION*[1]

The EGSP-West Virginia #5 well is located in Mason County, West Virginia, approximately five miles northeast of the town of Point Pleasant (Figures 1, 5A and Table 1).

GEOLOGY

The well site is located on the western edge of the Huntington-Pittsburgh Basin. No local geological structures have been mapped in the area. Bedrock is composed of Permian and Pennsylvanian cyclic coal sediments which are covered with Quaternary sediments along the Ohio River (Figure 5A). The stratigraphic section in the well consists of the Huron Shale, Java Shale, West Falls Formation and the Onondaga Limestone. Core point is 2,668' and termination depth 3,406' for a total of 738' of core retrieved from the well (Figure 5G).

PRODUCTION DATA*[2]

Two intervals of the West Virginia #5 well were stimulated. Interval 2,730'-3,042' in the Huron Member of the Ohio Shale was stimulated with a cryogenic type treatment resulting in an initial open flow of 456 mcf/day. Interval 3,348'-3,374' in the Rhinestreet Member of the West Falls Formation was stimulated by foam fracturing and the resulting initial open flow was 50 mcf/day. This interval was immediately flooded out, presumably by salt water from the underlying Onondaga Limestone (Overbey, personal communication).

CORING-INDUCED FRACTURES

A very strong N60°E to E-W trend is displayed by the petal fractures in the core. The trend is consistent throughout the stratigraphic section and aligns with the mechanical test results (Figure 5G). Disc fracture frequency is average with a decrease in frequency with depth.

NATURAL FRACTURES*[3]

Joints are found primarily in the Huron Member of the Ohio Shale, but a few are also found in the West Falls Formation (Figure 5G). The joint composite rose diagram shows three peaks: N60°-70°W, N70°-80°E and N40°-50°W. Fractures of the N70°-80°E set are found throughout the core, whereas fractures of the N40°-50°W set are restricted to the lower portion of the Huron Member of the Ohio Shale (Figure 5G).

Over one third of the joints in the core are mineralized, with either calcite, dolomite, anhydrite, or barite, in crystallized form or as massive coatings, sparsely covering the fracture surface. All of the mineralized fractures are found in the Huron Member of the Ohio Shale. The fractures with calcite mineralization generally strike N70°-80°E, whereas the fractures with dolomite mineralization generally strike N40°-70°W and are concentrated in a zone between 2,870' and 2,890'. The N-N30°E joint system is not mineralized. This preference in fracture mineralization suggests that one fracture set formed, or was open, at a time different from that of the other fracture set. If true, each set would have been exposed to fluid pressure and temperature conditions and groundwater chemistries different from that of the other set, resulting in the formation of different minerals. No abutting relationships were found in the core to confirm this interpretation.

The calcite mineralized N70°-80°E set has nearly the same orientation as the coring-induced fractures. Therefore, it is possible that these natural fractures formed under the same stress conditions responsible for the coring-induced fractures. This would make the N70°-80°E set the most recent because it follows the current stress or rock fabric anisotropy. The fractures in this set also parallel slickenside trends in this core, suggesting that they may have formed as extension fractures under compression from the northeast during formation of the Burning Springs Anticline. The N40°-50°W natural fracture set is nearly orthogonal to the trend of the central Appalachians and probably formed as an extension fracture set under tectonic compressive stresses during the Allegheny Orogeny. The N-N30°E joints parallel the central Appalachians and may have formed as a release fracture set as Paleozoic tectonic stresses were relaxed.

FAULTS AND SLICKENSIDES

Only five faults occur in the core: one in the Chagrin Shale, three in the Hanover Shale and one in the Rhinestreet Shale. The strike of the fault planes trends N10°-20°W, with movement on the faults normal to the strike and parallel to the N70°-80°E joint system (Figure 5G). This alignment suggests that the faults formed under the same stress system that was produced by the Allegheny deformation. Due to the lack of faults present, a reasonable assumption is that no major detachment has taken place this far west of the Allegheny Front in the Upper Devonian section. Drilling to the west in the Ohio #6 series wells indicates there may be some thrusting in the stratigraphically higher Berea Sandstone-Bedford Shale sequence.

*[1] p. 126

*[2] p. 126

*[3] p. 127.

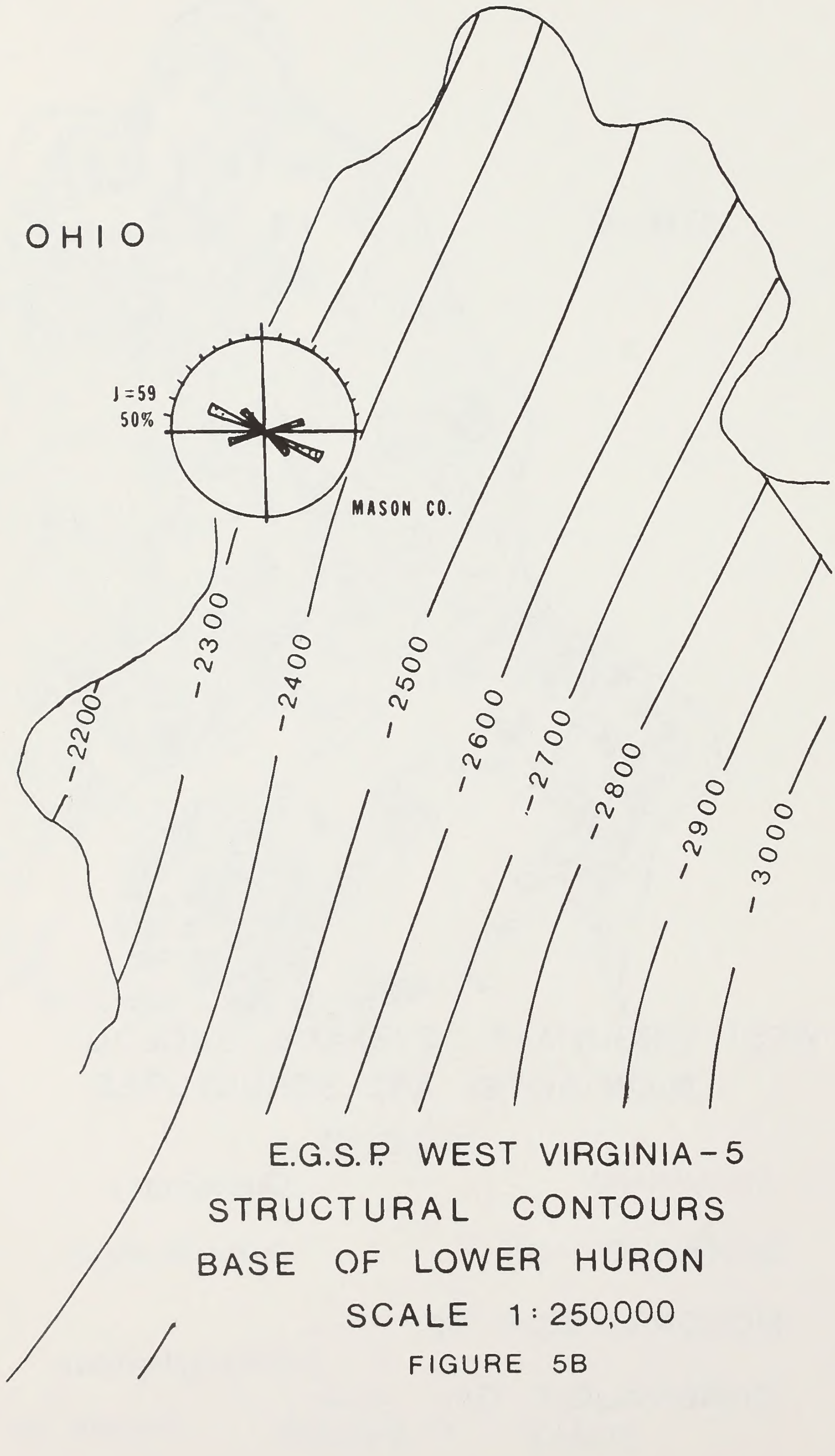
E.G.S.P. WEST VIRGINIA-5 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

LEGEND

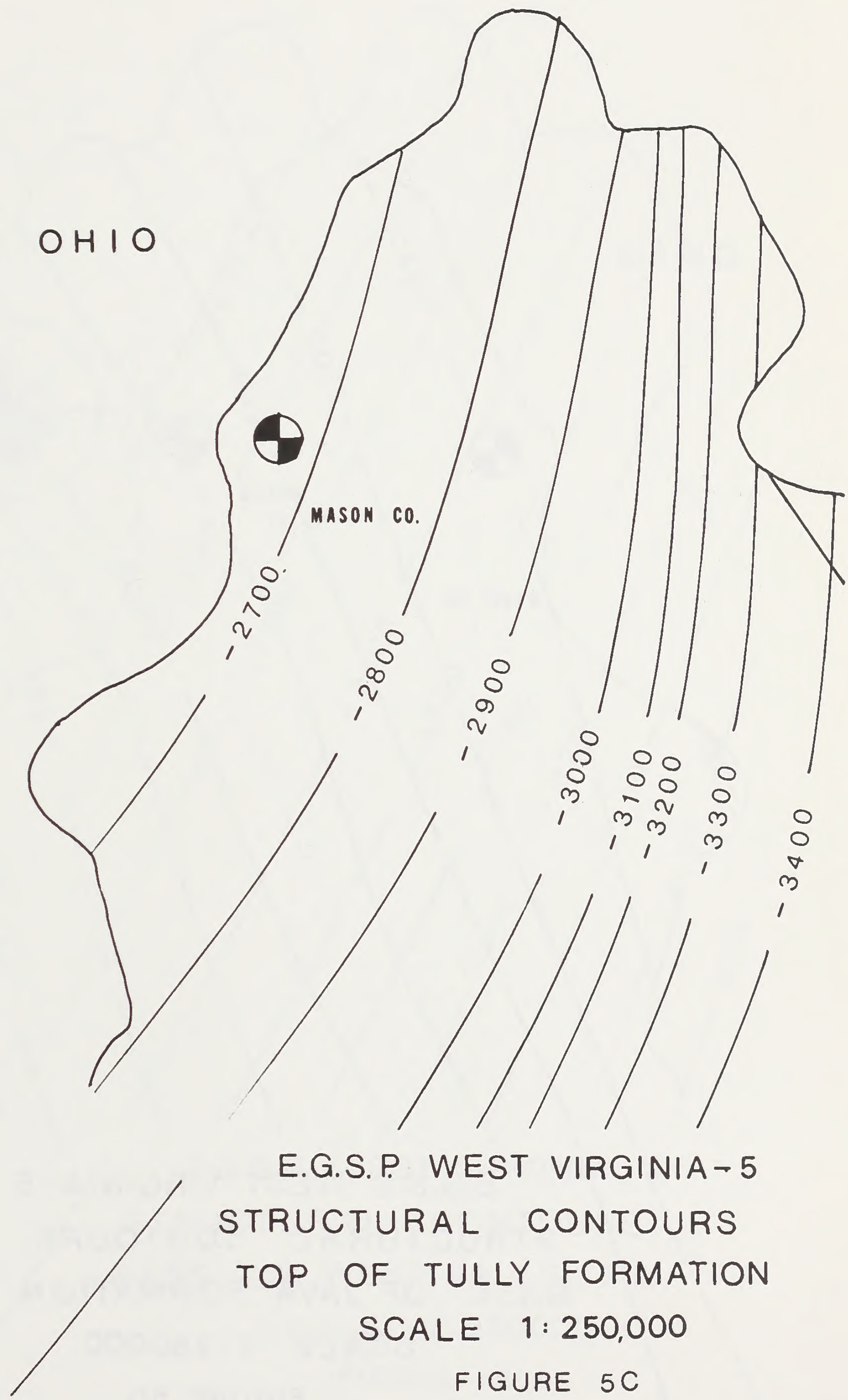
Qal	ALLUVIUM	Quaternary
Pd	DUNKARD Gp.	Perm. or Penn.
Ᵽm	MONONGAHELA Gp.	Pennsylvanian
Ᵽc	CONEMAUGH Gp.	Pennsylvanian

SCALE 1 : 250,000

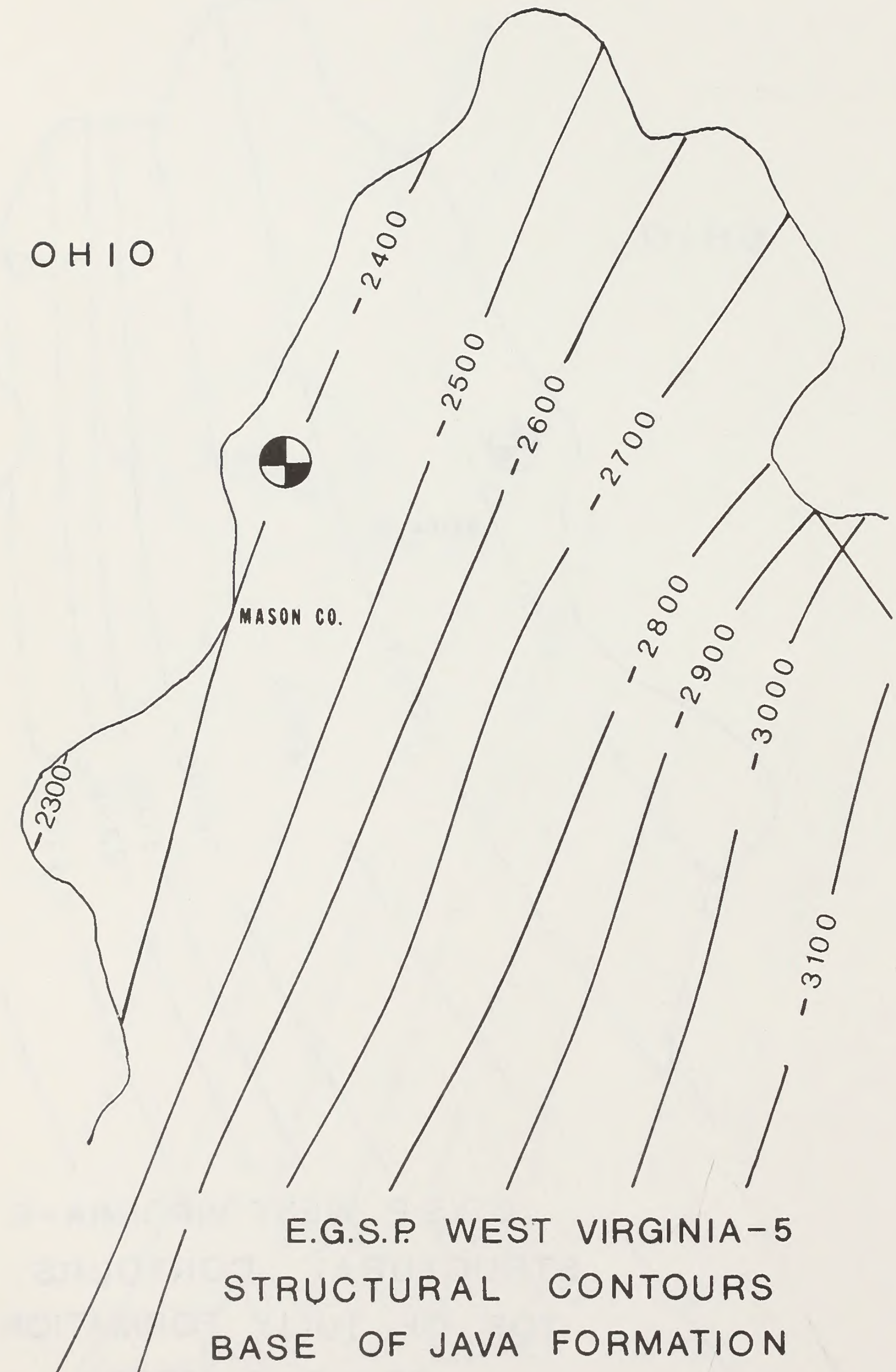
FIGURE 5A



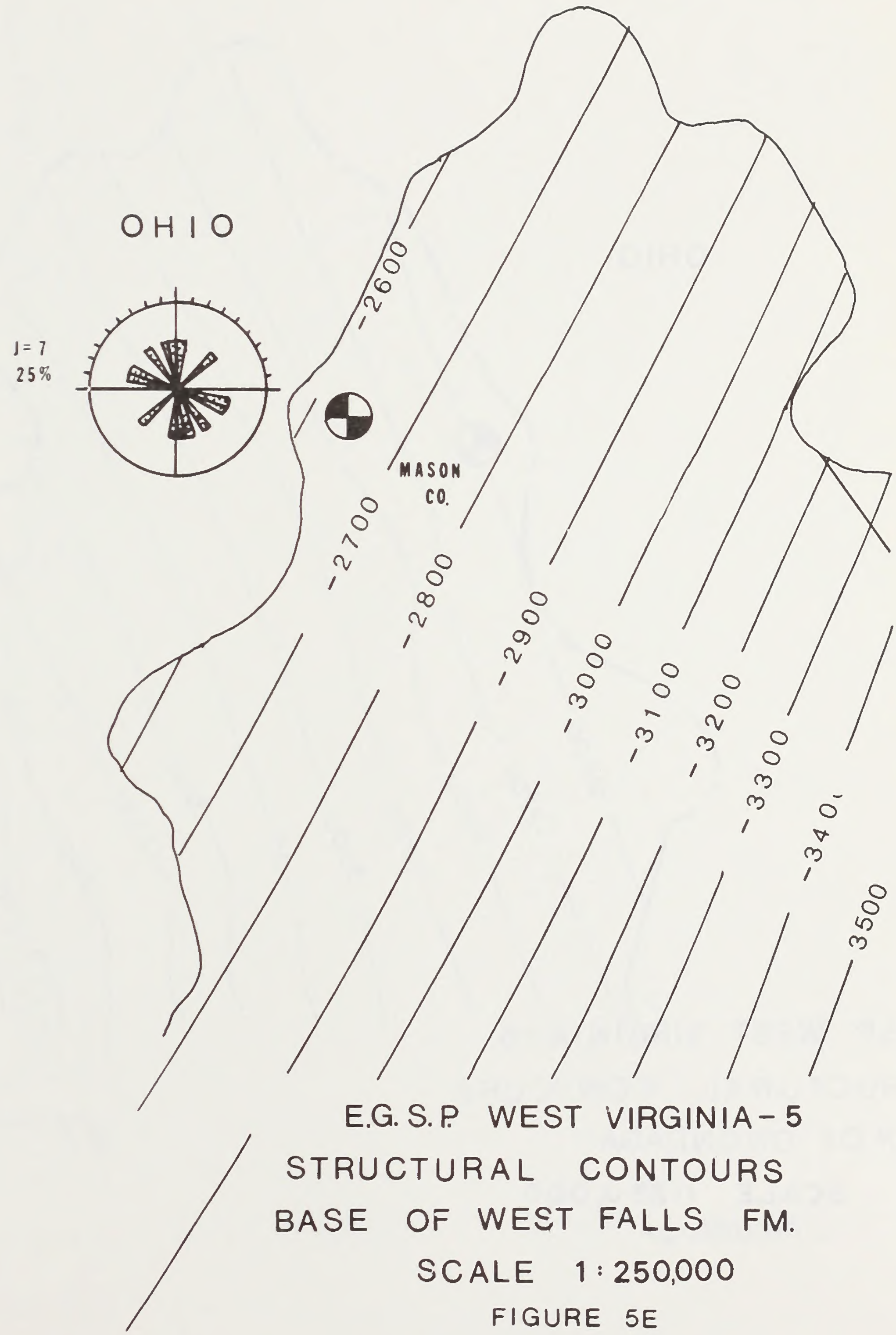
E.G.S.P. WEST VIRGINIA-5
STRUCTURAL CONTOURS
BASE OF LOWER HURON
SCALE 1:250,000
FIGURE 5B



E.G.S.P. WEST VIRGINIA-5
STRUCTURAL CONTOURS
TOP OF TULLY FORMATION
SCALE 1:250,000
FIGURE 5C



E.G.S.P. WEST VIRGINIA-5
STRUCTURAL CONTOURS
BASE OF JAVA FORMATION
SCALE 1:250000
FIGURE 5D



E.G.S.P. WEST VIRGINIA-5
STRUCTURAL CONTOURS
BASE OF WEST FALLS FM.
SCALE 1:250,000
FIGURE 5E

E.G.S.P. WEST VIRGINIA-5
STRUCTURAL CONTOURS
TOP OF ONONDAGA
SCALE 1:250,000
FIGURE 5F

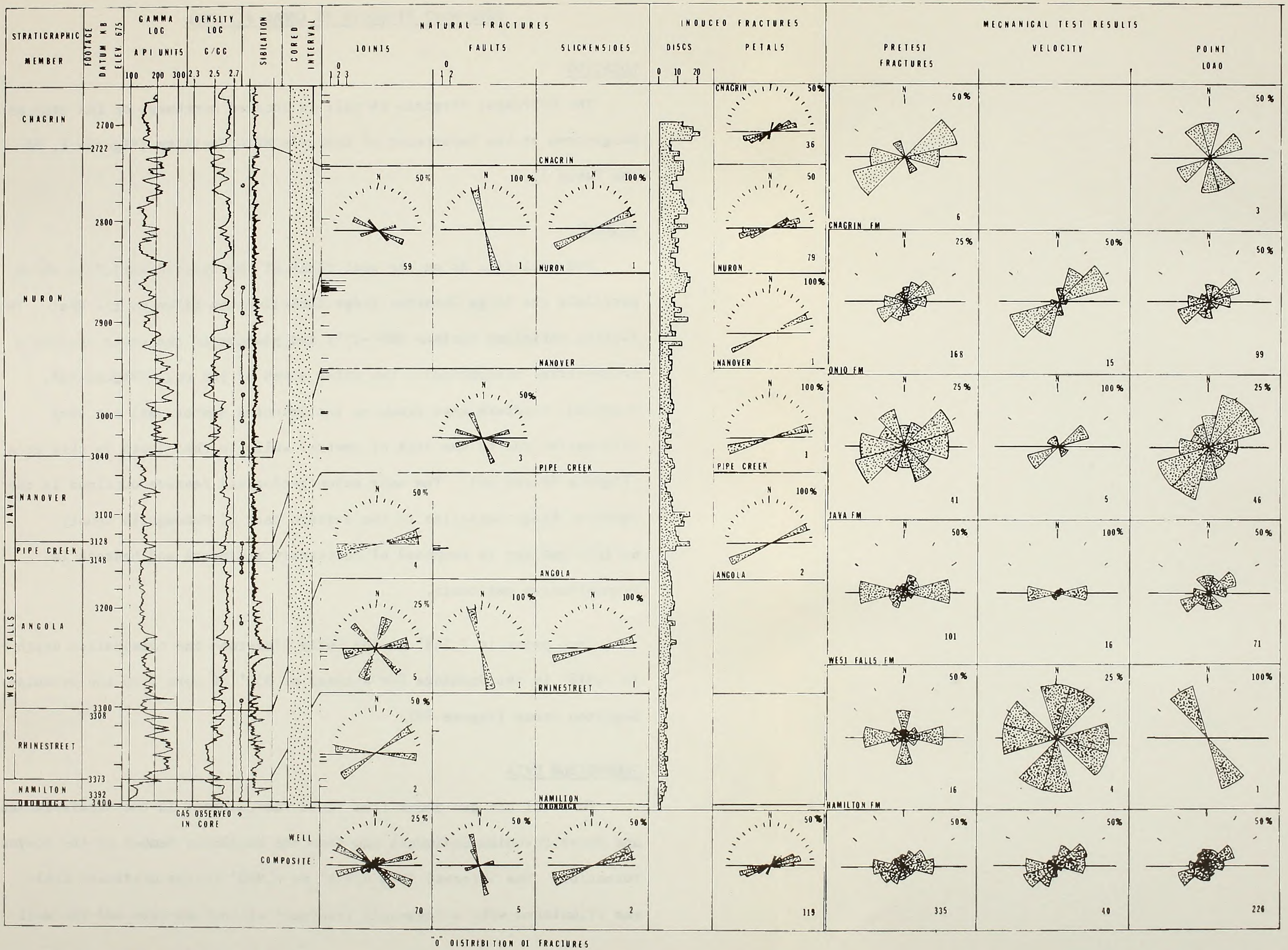


FIGURE 5C E G S P WEST VIRGINIA 5 WELL SUMMARY

CLIFFS MINERALS, INC.

EGSP-WEST VIRGINIA #6 (MERC #1) WELL

LOCATION

The EGSP-West Virginia #6 well is located northwest of the city of Morgantown at the Department of Energy's METC Facility (Figures 1, 6A and Table 1).

GEOLOGY

The well site is on the west flank of the Fayette Anticline which parallels the large Chestnut Ridge Anticline ten miles to the east. The Fayette Anticline strikes N20°-25°E and plunges to the south against a cross-strike discontinuity two miles south of the well (Figure 6A). Detailed structure maps drawn on the Devonian Members are not very informative due to the lack of control wells to that depth in this area (Figures 6B and 6C). The only major geological feature outlined is the Chestnut Ridge Anticline in the eastern part of Monongalia County. Surface geology is composed of Quaternary sediments and bedrock is Pennsylvanian sediments.

Core point is 7,168' in the Tully Limestone and termination depth is 7,518' in the Onondaga for a total of 350' of core from the Devonian Hamilton Group (Figure 6F).

PRODUCTION DATA

The well has gas shows from seven sand members in the Mississippian and Upper Devonian sediments and from the Middlesex Member of the Sonyea Formation. The interval from 6,910' to 6,990' in the Middlesex Shale was stimulated with a foam-acid treatment without success and the well

is presently shut in (A. I. Horton, 1981). All the gas occurrences are above the cored section of the well.

CORING-INDUCED FRACTURES

The fissility of the shale is probably the reason that no petal or petal centerline fractures were observed in the section. The disc fractures, however, are abundant and probably result from a combination of the overburden stress unloading which exceeds 8,000 psi at these depths and the fissile character of the shale (Figure 6F).

NATURAL FRACTURES

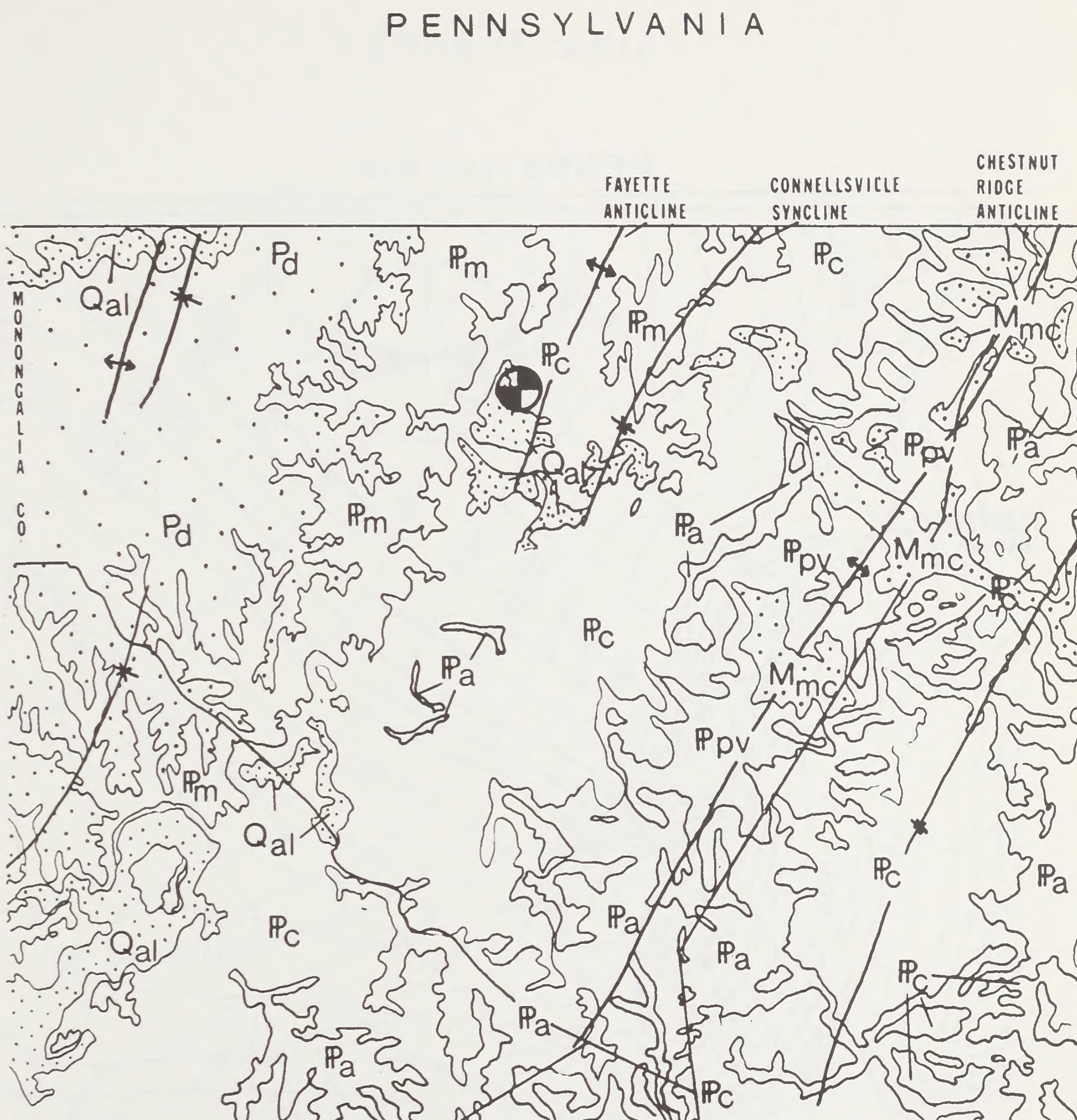
Most fractures in the core occur in shales as opposed to the more competent limestones. The heavily mineralized fractures are usually found adjacent to lime concretions, contacts with limestones, or in shales interbedded in the limestones. Also observed is that all movement on fault planes took place before mineralization of joints adjacent to concretions, as none of the joints are offset by slickensides. By observing the strike of the joints and the direction of movement on the faults (Figures 6E and 6F), it is clear that these features are associated with the SE to NW deformational stress of the Allegheny Orogeny. Therefore the joints are younger than the faults and their origin can either be attributed to the last event of the Allegheny Orogeny or a relaxation of stresses causing tension normal to the strike of the joints. Mineralization in the fractures is often fibrous and indicates tensional stress parallel to the attitude of the fiber axes during crystallization. The fibers are usually perpendicular to the joint and fault surfaces.

Two major joint trends appear in the West Virginia #6 core. The primary trend is N80°-90°E and the secondary N60°-70°W (Figure 6F). The N60°-70°W trend is normal to the fold axis in the plateau region and is probably a direct result of the tectonic stress that formed the folds.

Faults are most abundant in the lower section of the Mahantango Shale and throughout the Marcellus Shale (Figure 6F). This distribution indicates that the high organic shale just above the Onondaga Limestone is a décollement zone. The fault composite rose diagram has two trends at N0°-30°E and at N20°-30°W (Figure 6D). The equal area projection of poles to the fault planes shows a low dip angle (0°-30°) with an overall E-NE dip which supports the décollement model. The scatter of fault strike is probably due to the calcareous concretions near which many of the fault planes occur. A strong N65°-75°W trend is displayed by the slickenside bearings (Figure 6E). The trend correlates very well with the stresses expected during the Allegheny Orogeny.

MECHANICAL TEST RESULTS

The majority of the test samples were taken from the Tully Limestone due to the high disc fracture frequency in the organic shale core (Figure 6F). A well-developed anisotropy is defined by the tests in the Tully, oriented normal to the major compressive stress projected during the Allegheny Orogeny. This orientation indicates rock fabric development at that time similar to the solution cleavage developed in the limestones of New York by T. Engelder (1980).

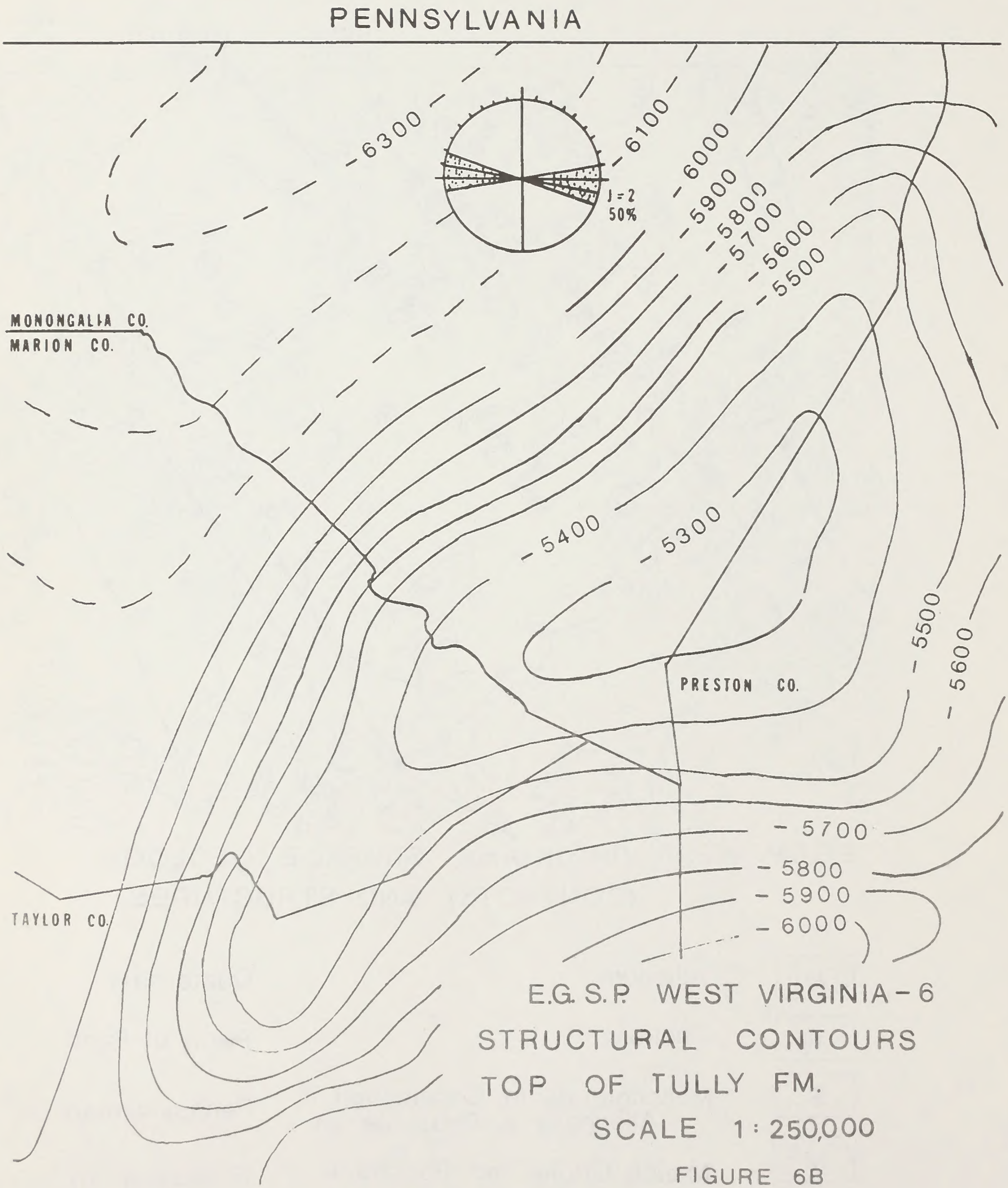


E.G.S.P. WEST VIRGINIA-6 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

Qal	Alluvium	Quaternary
Pd	Dunkard	Perm. or Penn.
ℙ	Monongahela m, Conemaugh c, Allegheny a, Pottsville pv	Pennsylvanian
M	Mauch Chunk mc, Pocono p	Mississippian

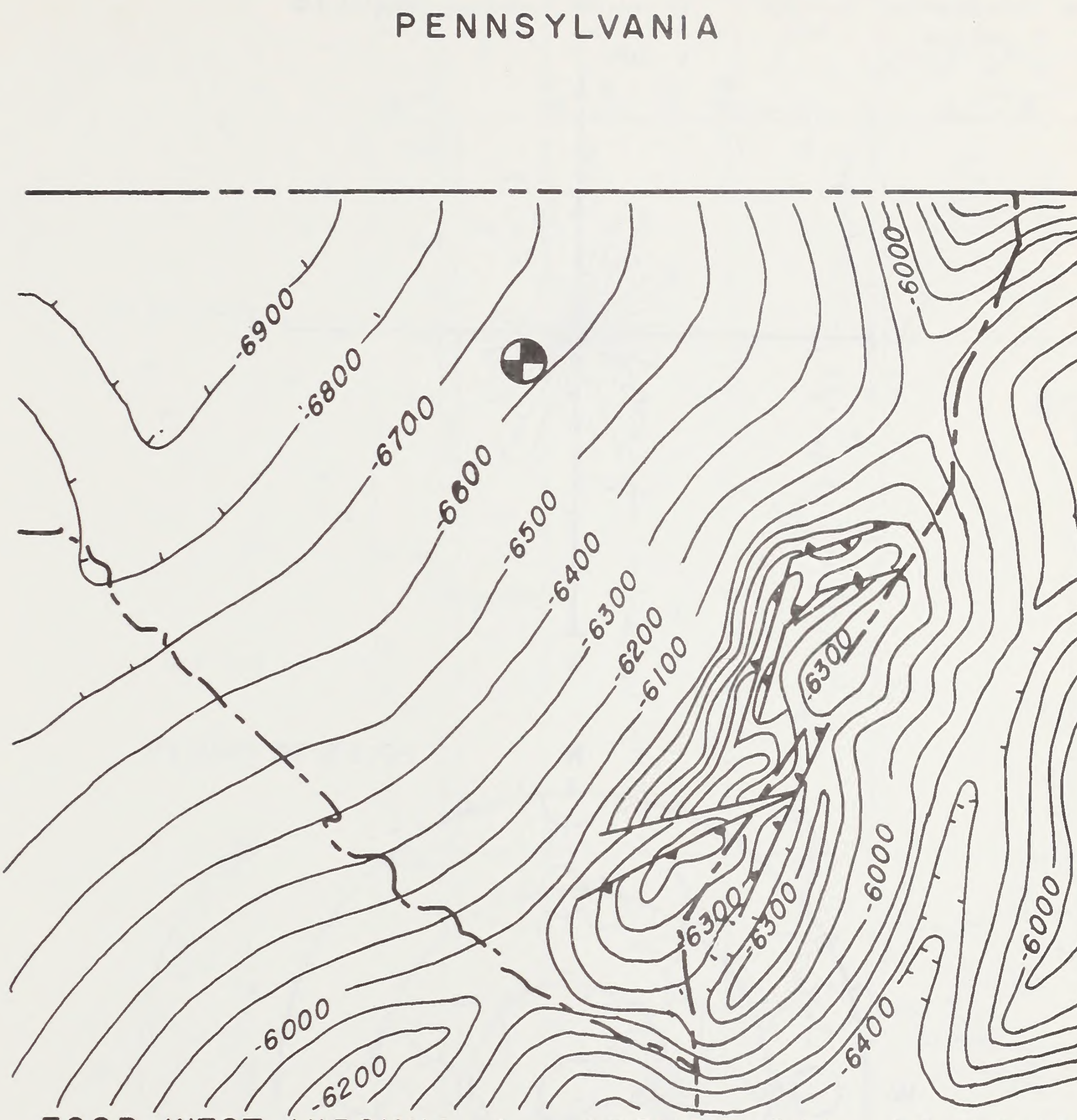
SCALE 1 : 250,000

FIGURE 6A



E.G.S.P. WEST VIRGINIA-6
STRUCTURAL CONTOURS
TOP OF TULLY FM.
SCALE 1:250,000

FIGURE 6B



E.G.S.P. WEST VIRGINIA-6 STRUCTURAL CONTOURS

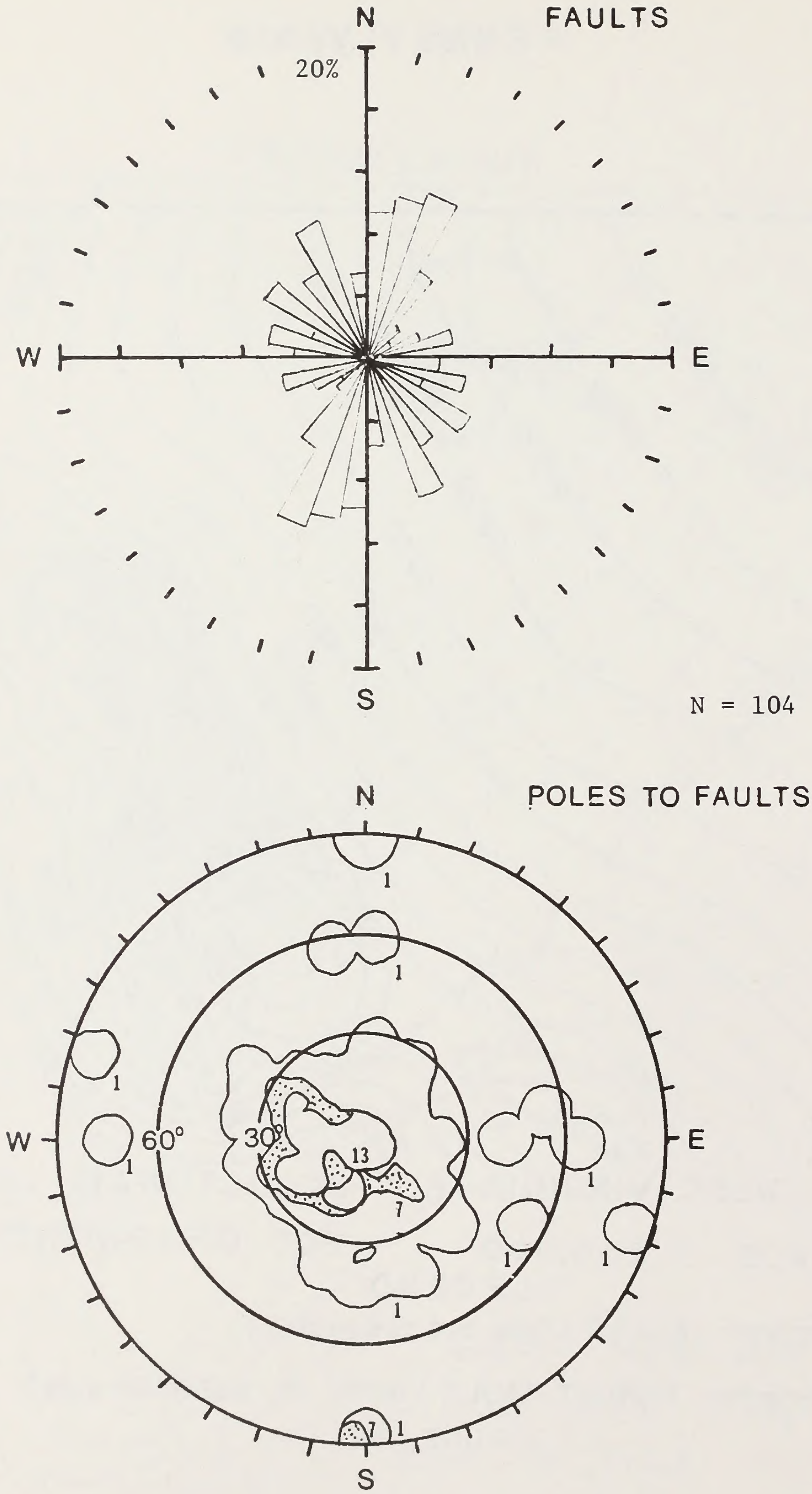
SCALE 1 250,000 TOP OF ONONDAGA

LEGEND

FAULT (type not designated)

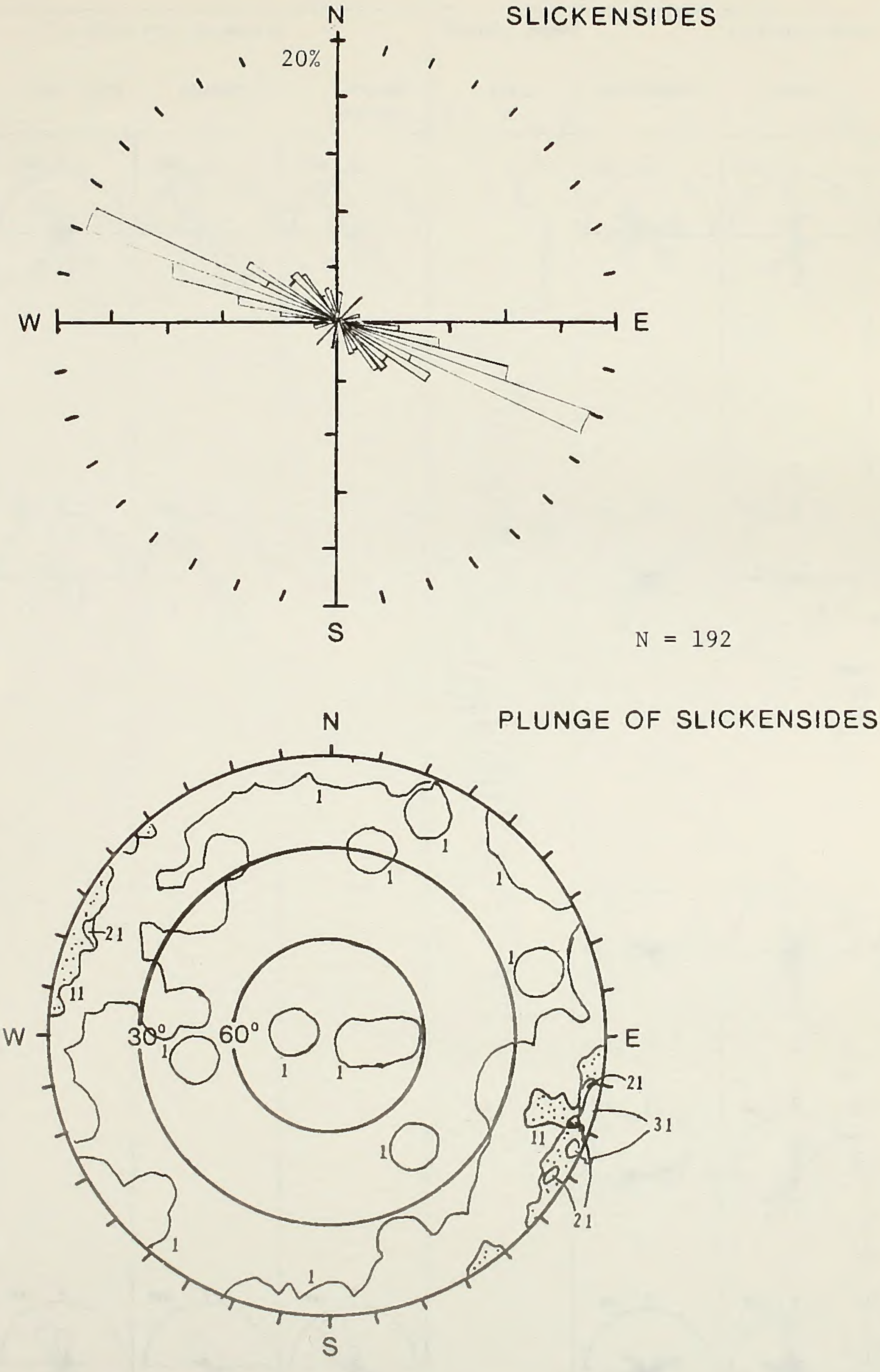
THRUST FAULT (teeth on upthrown side)

FIGURE 6C



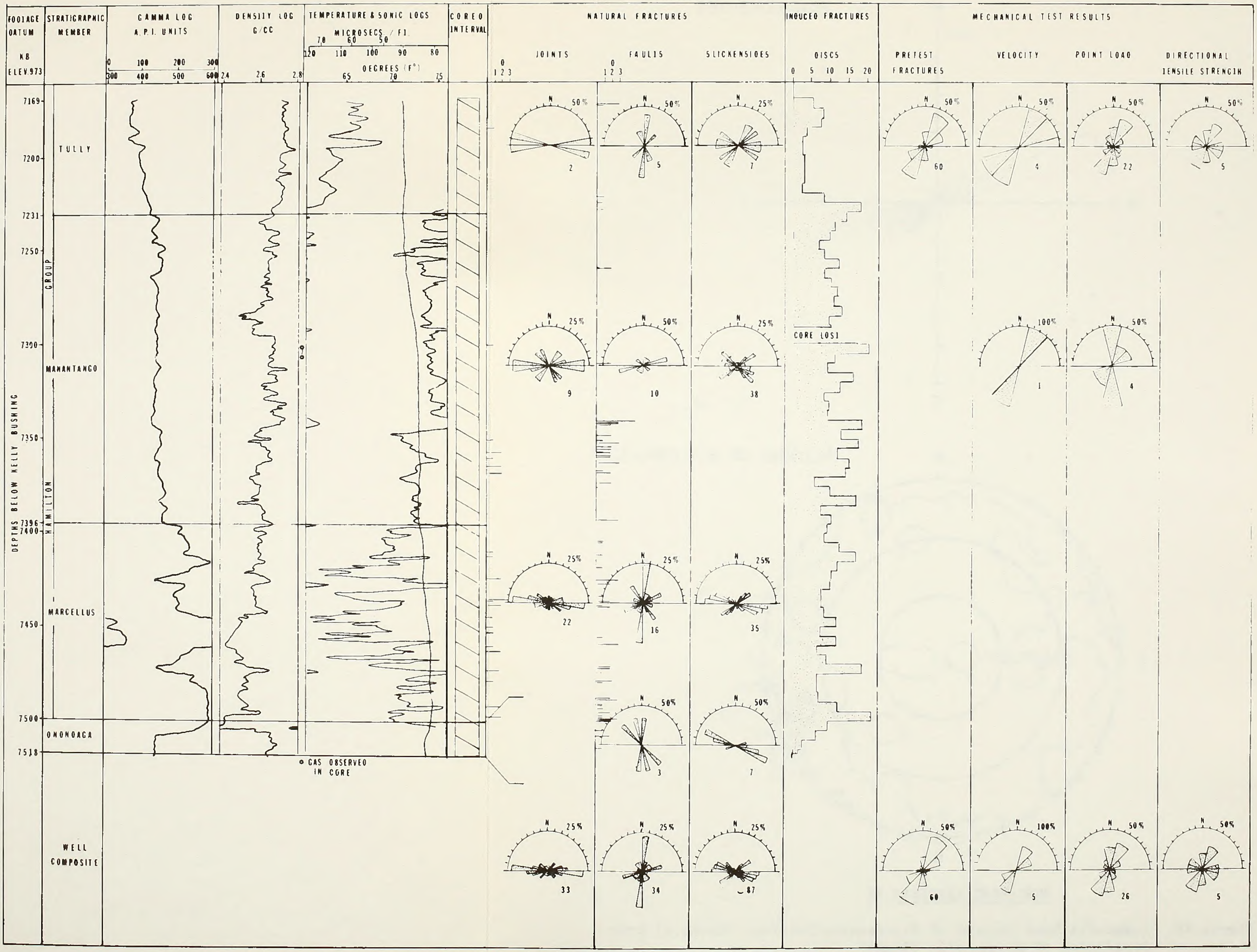
EGSP-WEST VIRGINIA #6

Figure 6D. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.



EGSP-WEST VIRGINIA #6

Figure 6E. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.



"D": DISTRIBUTION OF FRACTURES

FIGURE 6 E.G.S.P. WEST VIRGINIA 6 WELL SUMMARY

CLIFFS MINERALS, INC.

EGSP-WEST VIRGINIA #7 (EMCH-PYLES #1) WELL

LOCATION

The EGSP-West Virginia #7 well is located in Wetzel County, approximately one mile northeast of New Martinsville on the Ohio River (Figures 1, 7A and Table 1).

GEOLOGY

The well site is on the crest of the New Martinsville Anticline which has a N40°E strike and is immediately north of a change in strike of the folds from E-NE to NE (Figure 7A). The bedrock consists of Pennsylvanian Age sediments in the Huntington-Pittsburgh Basin. Core point is in the Rhinestreet Shale at a depth of 6,102' and termination depth is 6,635' in the Onondaga Limestone for a total of 533' of core recovered from the well (Figure 7E).

PRODUCTION DATA

To date no commercial gas production has been obtained from this well.

CORING-INDUCED FRACTURES

A total of nine petal fractures occurs in the West Virginia #7 core: five in the Rhinestreet and four in the Sonyea Formations. The change in strike from N10°-20°W to N60°-70°E from the Rhinestreet to the Sonyea seems to indicate a change in the stress fields between these two members (Figure 7E). Disc fracture frequency, which is very high in this well, has probably resulted from large overburden stress unloading during coring.

NATURAL FRACTURES

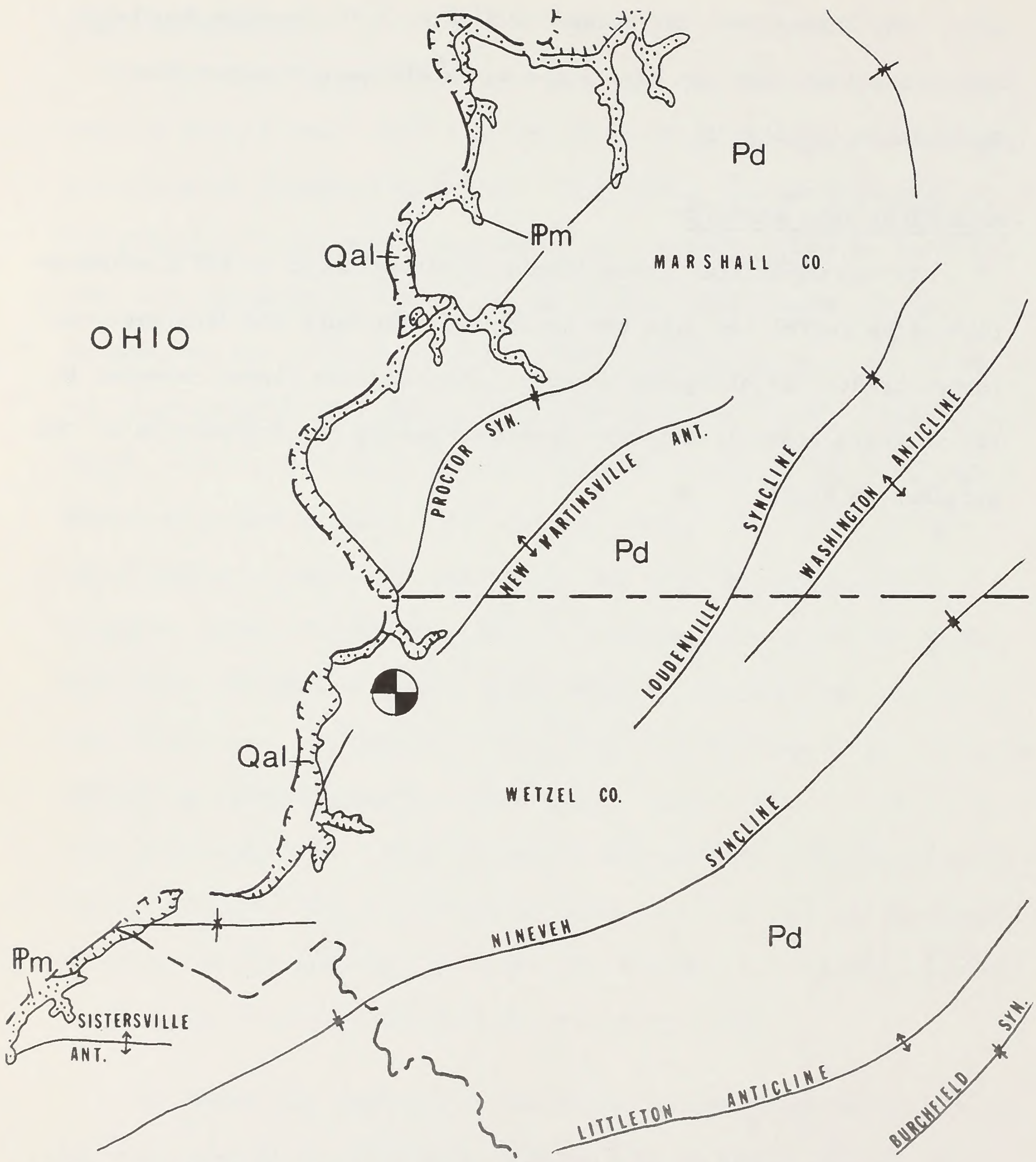
Joints show an overall NW trend similar to the direction of movement on fault planes. Both correspond to the stress projected during the Allegheny Orogeny (Figure 7C). The extent of mineralization in all the joints plus the fibrous nature of the carbonate filling indicate that high fluid pressures characterized the mineralizing sequence. An interesting feature of this core is the association of a zone of vertical mineralized joints with a limey concretion at 6,498' in the Geneseo Shale. The ten-foot high parallel fracture set strikes N54°W above a shale-concretion contact. The western edge of the concretion was cored and displays slickensides that dip to the northwest above and to the southwest below, the nodule. Direction of movement along the faults is N60°-70°W. Movement occurred within bedding planes which wrap around the concretion. The bedding shows a variable dip from 6,498' to 6,512' indicating more concretions in the shale. From 6,512.0' to 6,520.5' a dark limestone occurs which may be the most western occurrence of the Tully Limestone. The joints are a direct result of stress developed in the shale due to deformation around the concretion. Overall jointing and faulting is normal to the fold axes in the area.

The faults are confined to the black organic shale facies and are not very numerous in this well. Variability in strike on the fault planes is due to the undulating surfaces caused by the concretions and by contacts with the limestone interbeds. Movement on the faults, however, is very consistent (N65°-75°W) and is perpendicular to the fold axes observed at surface. The effect of the stress developed by the Allegheny Orogeny is evident in the jointing and fault movement in this

core. The Rhinestreet and Geneseo Shales contain the most faults, indicating that they may have acted as décollement horizons during deformation (Figure 7E).

MECHANICAL TEST RESULTS

All the mechanical tests display a strong north to N30°E orientation which correlates with the geological structure and deformational forces created by Allegheny Orogeny. The weakness planes expected in the rock are probably a fabric developed during the deformation of the Appalachian Basin.



E.G.S.P. WEST VIRGINIA-7 SURFACE GEOLOGY (CONTACTS) AND STRUCTURES

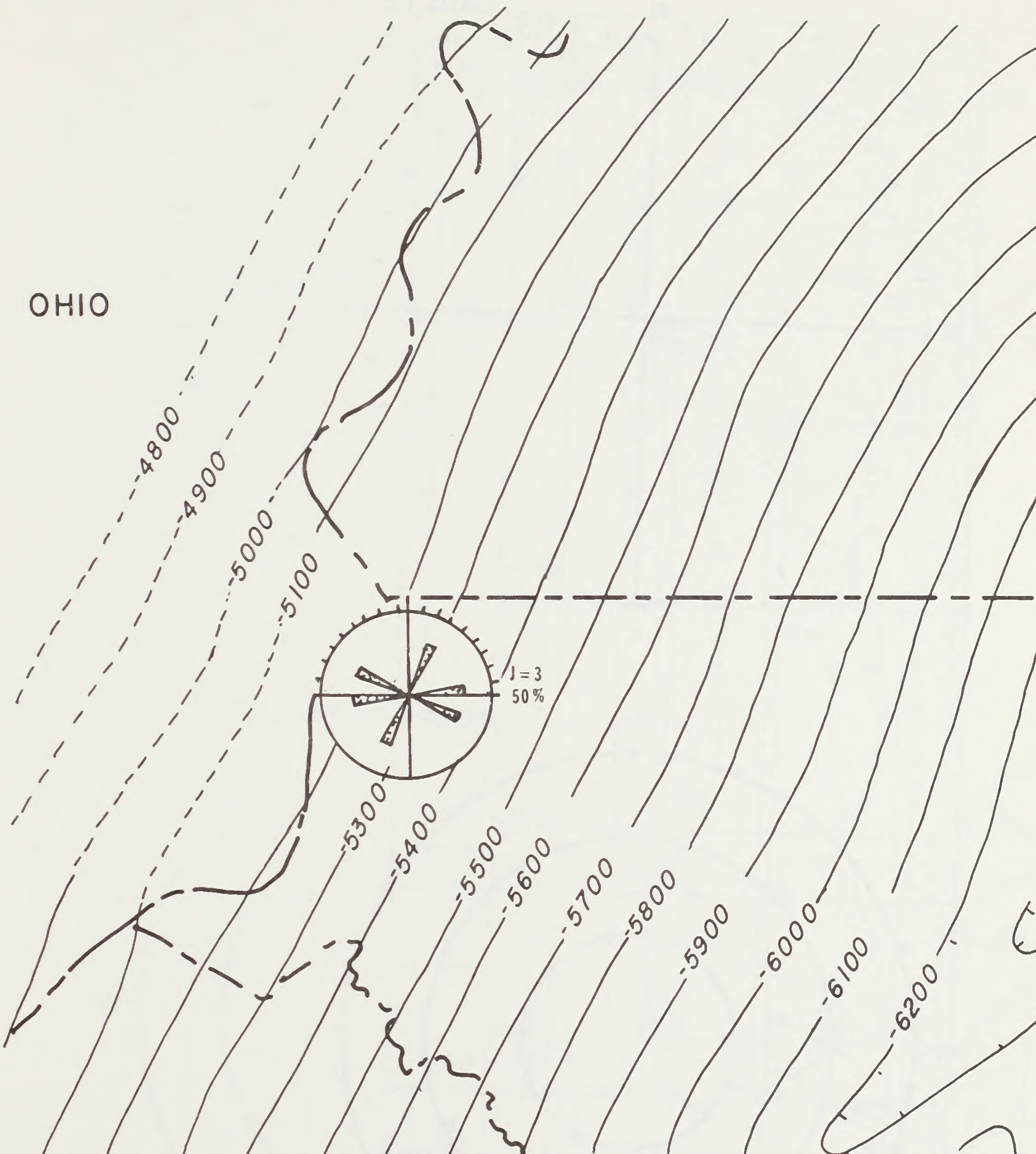
LEGEND

Qal	ALLUVIUM	Quaternary
Pd	DUNKARD Gp.	Permian or Pennsylvanian
Pm	MONONGAHELA Fm.	Pennsylvanian

ANTICLINE SYNCLINE

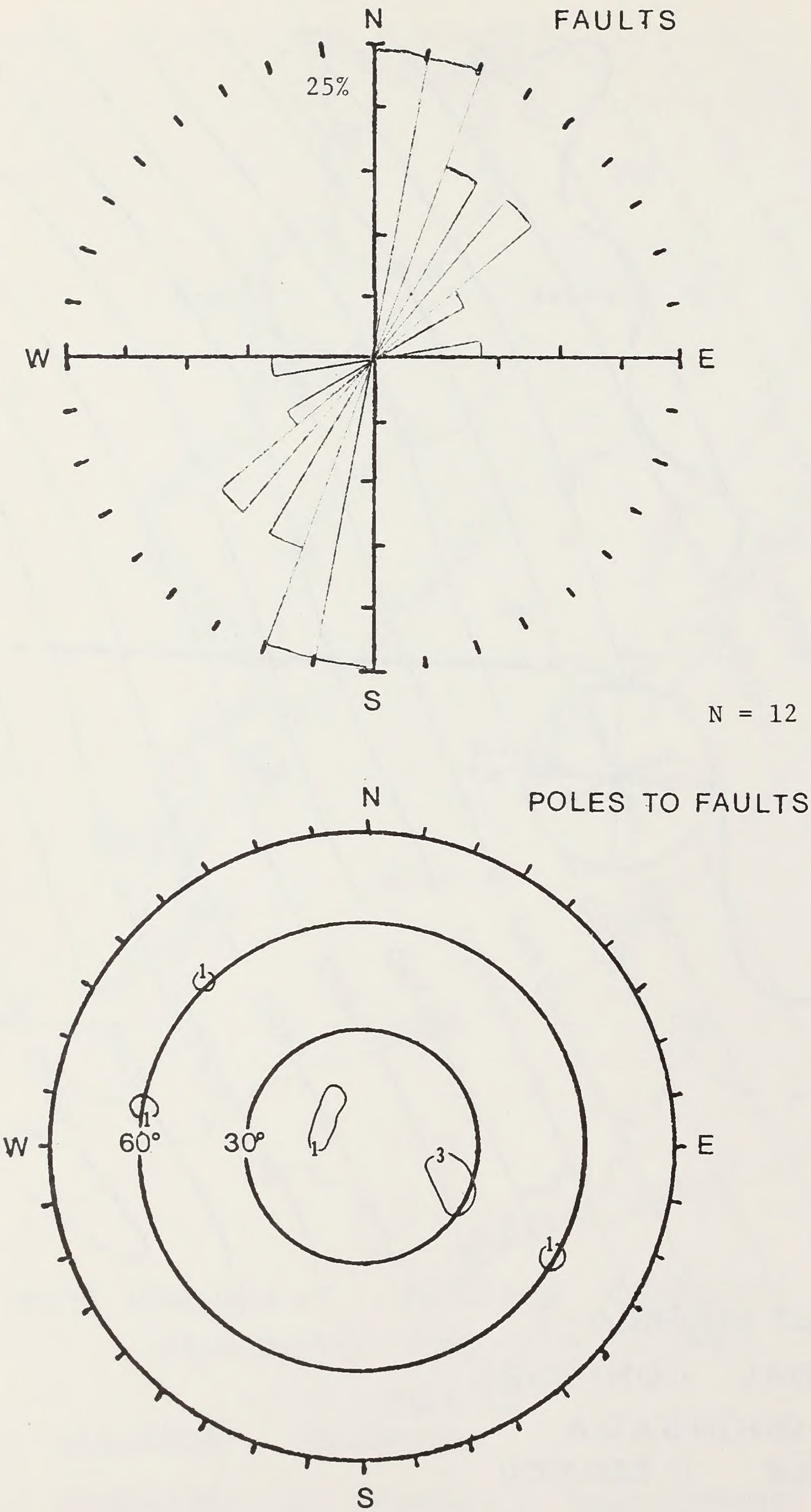
SCALE 1 : 250,000

FIGURE 7A



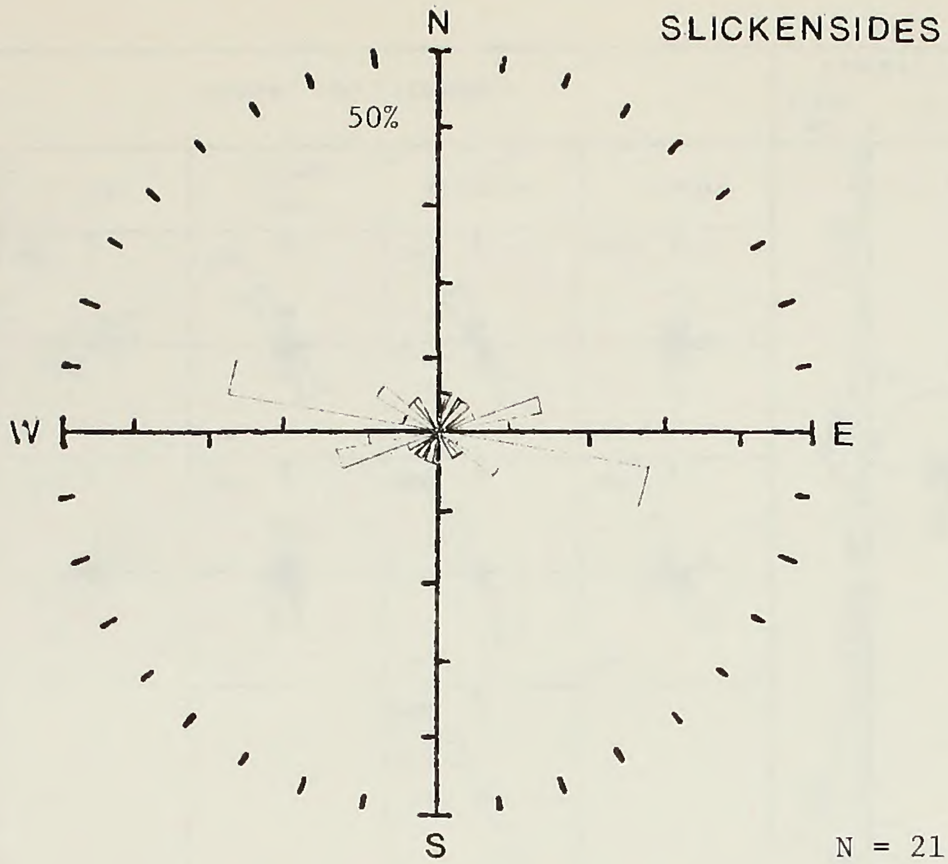
E.G.S.P. WEST VIRGINIA-7
STRUCTURAL CONTOURS
TOP OF ONONDAGA
SCALE 1 : 250,000

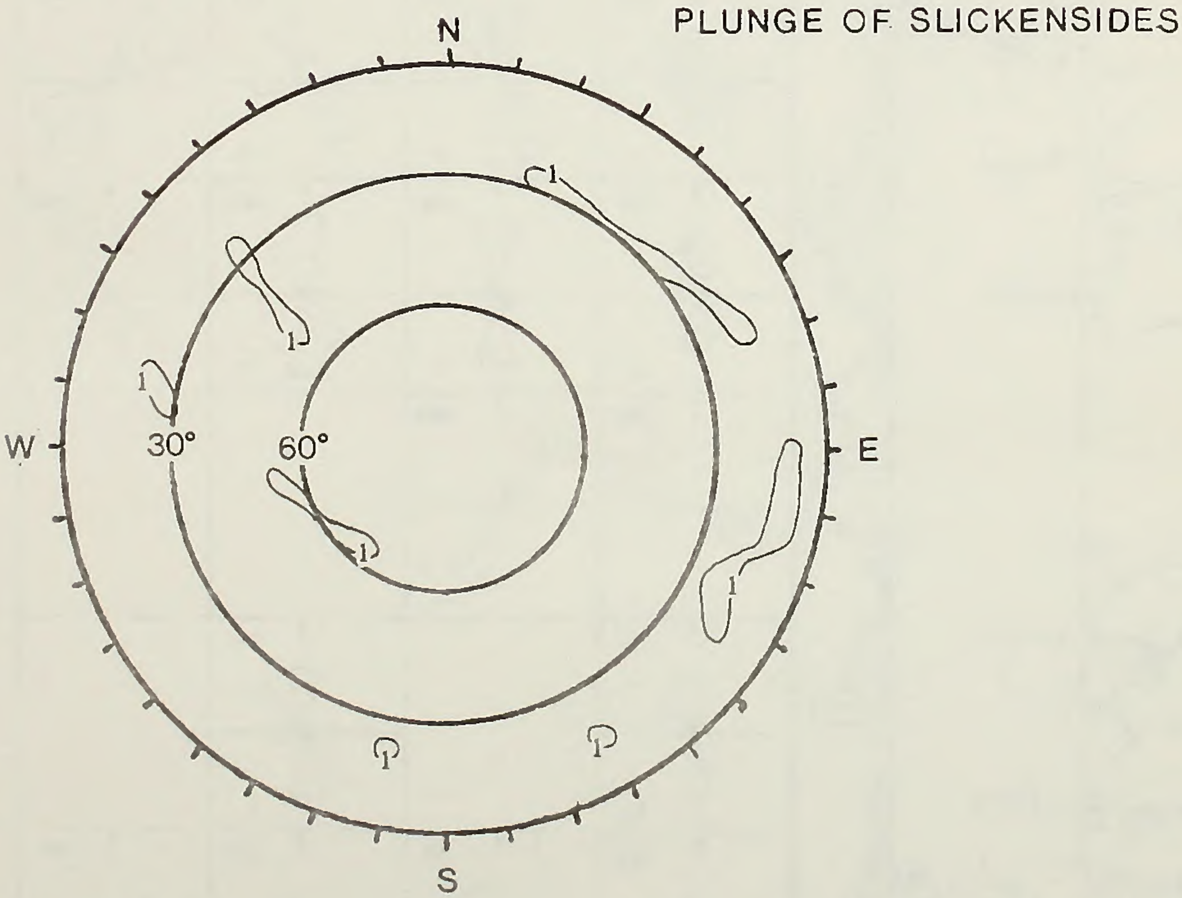
FIGURE 7B



EGSP-WEST VIRGINIA #7

Figure 7C. Composite Rose Diagram of Fault Strikes and Equal Area Projection of Poles to Fault Surfaces.





EGSP-WEST VIRGINIA #7

Figure 7D. Composite Rose Diagram of Slickenside Bearings and Equal Area Projection of Slickenside Plunge.

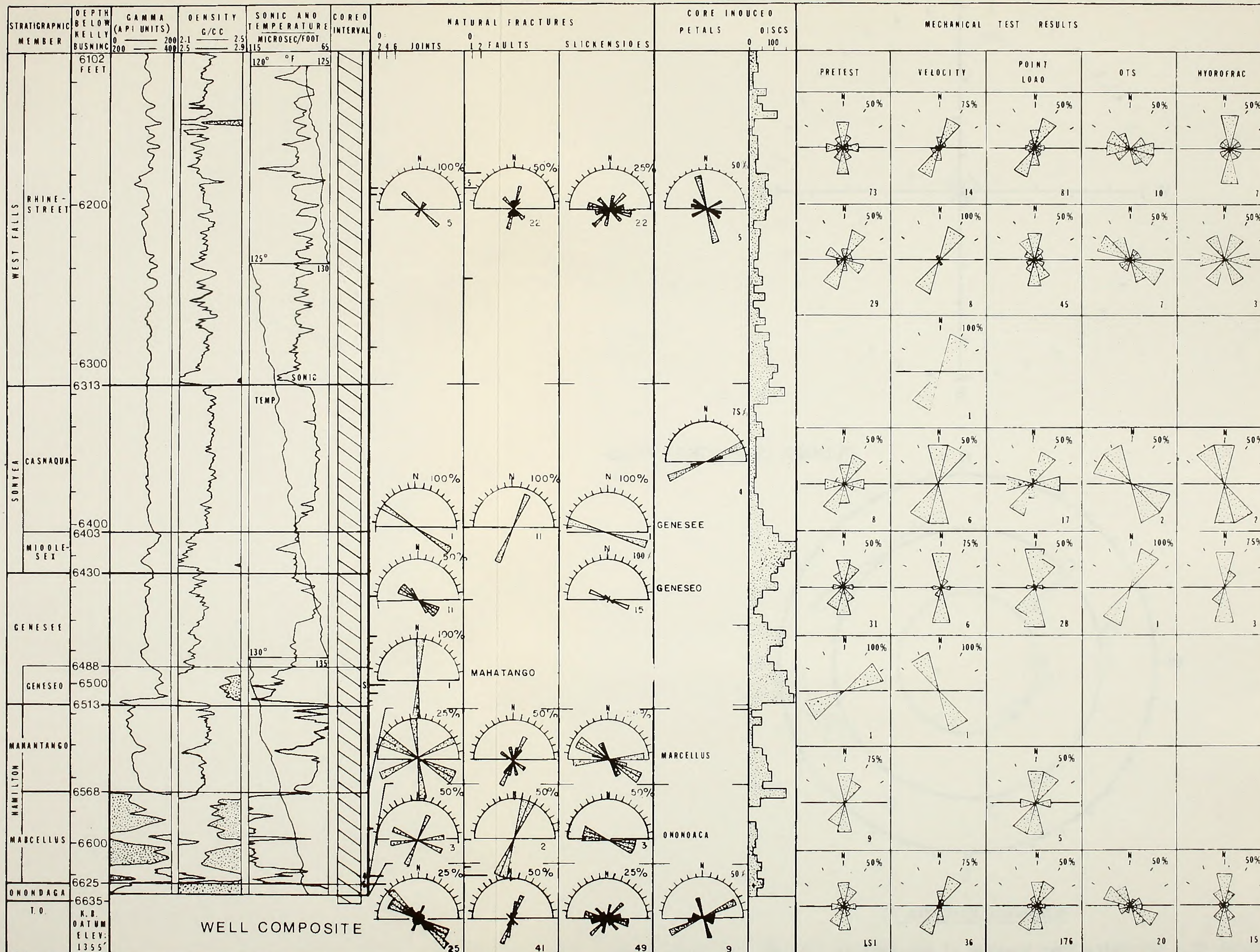


Figure 7E EGSP-West Virginia #7 Well Summary D = FRACTURE DISTRIBUTION CLIFFS MINERALS, INC

VOLUME II BIBLIOGRAPHY

Aeromagnetic Map of West Virginia: 1978. West Virginia Geological Survey.

Byerer, C. W. and Rhoades, S. J., 1976, "Lithologic Description of Core Material from Glen Gery #5-745 Well, Rose Township, Carroll County, Ohio." Morgantown Energy Research Center, MERC/TPR-7616.

Byerer, C. W., Trumbo, D. B., and Rhoades, S. J., 1976, "Lithologic Description of Cored Wells #11940 and #12401 in the Devonian Shale in the Cottageville, West Virginia Area", Morgantown Energy Research Center, MERC/TPR-7617.

Cardwell, Dudley H., Erwin, Robert B. and Woodward, Herbert P., 1968, Geologic Map of West Virginia, West Virginia Geological Survey, Morgantown, West Virginia.

Cate, A. S., 1962, "Subsurface Structure of the Plateau Region of North Central and Western Pennsylvania on Top of the Oriskany Formation": Pennsylvania Department of Environmental Resources, Topographic and Geologic Survey, Map Number 9.

Cliffs Minerals, Inc., 1980, Phase I Report - Field Operations, EGSP-Ohio #3 Well, Knox County, Ohio.

------, 1979, Phase I Report - Field Operations, EGSP-Ohio #5 Well, Lorain County, Ohio.

------, 1979, Phase I Report - Field Operations, EGSP-Ohio #6-1 Well, Gallia County, Ohio.

------, 1980, Phase II Report - Preliminary Laboratory Results, EGSP-Kentucky #4 Well, Johnson County, Kentucky.

------, 1980, Phase II Report - Preliminary Laboratory Results, EGSP-New York #1 Well, Allegany County, New York.

------, 1980, Phase II Report - Preliminary Laboratory Results, EGSP-New #3 Well, Steuben County, New York.

------, 1980, Phase II Report - Preliminary Laboratory Results, EGSP-New York #4 Well, Steuben County, New York.

------, 1980, Phase II Report - Preliminary Laboratory Results, EGSP-Tennessee #9 Well, Grainger County, Tennessee.

Cobb, L. B., et al., 1979, "Geologic Evaluation and Drilling Prognosis for EGSP-Tennessee #9 Well, Grainger County, Tennessee": Gruy Federal, Inc., Houston, Texas.

Dillman, S. B. and Ettensohn, F. R., 1980, "Structure on Contour Map on the Base of the Cleveland Shale Member (Unit 1) of the Ohio Shale in Eastern Kentucky". University of Kentucky Research Group, Morgantown Energy Technology Center/Eastern Gas Shales Project (METC/EGSP Series No. 514).

------, 1980, "Structure on Contour Map on the Base of the Three Lick Bed (Unit 2) of the Ohio Shale in Eastern Kentucky": University of Kentucky Research Group, Morgantown Energy Technology Center/Eastern Gas Shales Project (METC/EGSP Series No. 513).

------, 1980, "Structure on Contour Map on the Base of the Middle Huron Shale Member (Unit 4) of the Ohio Shale in Eastern Kentucky". University of Kentucky Research Group, Morgantown Energy Technology Center/Eastern Gas Shales Project (METC/EGSP Series No. 511).

------, 1980, "Structure on Contour Map on the Base of the Lower Huron Shale Member (Unit 5) of the Ohio Shale in Eastern Kentucky". University of Kentucky Research Group, Morgantown Energy Technology Center/Eastern Gas Shales Project (METC/EGSP Series No. 510).

------, 1980, "Structure on Contour Map on the Base of the Java Formation/ Olentangy Shale (Unit 6) of the Ohio Shale in Eastern Kentucky". University of Kentucky Research Group, Morgantown Energy Technology Center/ Eastern Gas Shales Project (METC/EGSP Series No. 509).

------, 1980, "Structure on Contour Map on the Base of the West Falls Formation (Rhinestreet Shale, Unit 7) of the Ohio Shale in Eastern Kentucky". University of Kentucky Research Group, Morgantown Energy Technology Center/Eastern Gas Shales Project (METC/EGSP Series No. 508).

Donohue, Anstey, and Morrill, 1981, "Shale Gas in the South Central Area of New York State, Part II - Experience of Locating and Drilling Four Shale Gas Wells in New York State." Report for USDOE Contract: DE-AC21-80MC12697.

Durney, D. W., and Ramsay, J. G., 1973, Incremental Strains Measured by Syntectonic Crystal Growth, in Gravity and Tectonics, K. Dejong and R. Scholten, eds.: John Wiley, New York, p. 67-96.

Engelder, Terry, 1979, "Mechanisms for Strain Within the Upper Devonian Clastic Sequence of the Appalachian Plateau, Western New York". American Journal of Science, Vol. 279, May 1979, p. 527-542.

Engelder, Terry and Geiser, Peter, 1980, "On the Use of Regional Joint Sets as Trajectories of Paleostress Fields During the Development of the Appalachian Plateau, New York". Journal of Geophysical Research, Vol. 85, No. B11, pages 6319-6341, November 10, 1980.

Evans, Mark A., 1980, "Fractures in Oriented Devonian Shale Cores from the Appalachian Basin," Master's Thesis, Geology Department, West Virginia University, Morgantown, West Viriginia, USDOE Contract Number DE-AC21-76MC05194.

Gray, J., 1982, Preliminary Structure Map of the Top of the "Big Lime" in Ohio, Ohio Geological Survey.
------, 1982, Preliminary Structure Map of the Top of the "Berea Sandstone" in Ohio, Ohio Geological Survey.

Gruy Federal, Inc., 1980, "Coring, Logging, Stimulation and Completion of EGSP-Tennessee #9 Well, Grainger County, Tennessee," Final Report, EGSP/USDOE Contract Number DE-RP-05-79MC0838.

Gwinn, V. E., 1964, "Thinskinned Tectonics in the Plateau and North Western Valley and Ridge Provinces of the Central Appalachians," Geological Society of America Bulletin, V. 75, P. 863-900.

Horton, Andrea I., 1981, "Comparative Analysis of Stimulations in the Eastern Gas Shales", Morgantown Energy Technology Center, DOE/METC-145.

Kehle, R. O., 1970, Analysis of Gravity Sliding and Orogenic Translation: Geol. Soc. Am. Bull., Vol. 18, pages 1641-1664.

Komar, C. A., Frohne, K. H., and Yost, A. B., 1978, Stimulation Technology: A Progress Review: Open File Report, USDOE-Morgantown Energy Technology Center, 68 p.

Kulander, B. R., Dean, S. L., and Barton, C. C., 1977, Fractographic Logging for Determination of Pre-core and Core-Induced Fractures-Nicholas Combs No. 7239 Well, Hazard, Kentucky: USERDA-Morgantown Energy Research Center, MERC-77/3, 44 p.

Larese, R. E., and Heald, M. T., 1977, Petrography of Selected Devonian Shale Core Samples From the CGTC 20403 and CGSC 11940 Wells, Lincoln and Jackson Counties, West Virginia: USERDA-Morgantown Energy Research Center, MERC/CR-77/6, 22 p.

Lee, Byungoh, et al., 1982, "Evaluation of Devonian Shale Reservoir Using Multi-Well Pressure Transient Testing Data", SPE/DOE paper 10838.

Lee, Kevin, 1980, "Subsurface Structure of the Eastern Kentucky Gas Field", West Virginia University, Department of Geology and Geography, DOE Contract No. DE-AC21-76ET12138.
METC, 1981, "Volume 2 - Main Body of Semi-Annual Report for the Unconventional Gas Recovery Program," Period Ending March 31, 1981, p. 3-26, DOE/METC/SP-1108.

Nuckols III, E. B., "Exploration Parameters Derived from Historical Devonian Shale Production in Western West Virginia". in An analysis of the Structural Parameters that Influence Gas Production from the Devonian Shale, Volume II: Data repository and reports published during fiscal year 1978-1979, West Virginia University, Department of Geology and Geography, annual progress report for USDOE Contract Number DE-AC21-76MC05194, October 1979.

Parrish, Jay B., 1978, "The Relationship of Geophysical and Remote Sensing Lineaments to Regional Structure and Kimberlite Intrusions in the Appalachian Plateau of Pennsylvania": Master of Science Thesis, Pennsylvania State University.

Renfro, H. B., and Feray, D. E., 1970, Geological Highway Map of the Mid-Atlantic Region: Map No. 4, AAPG, Tulsa, Oklahoma.

Root, S. I., and Hoskins, D. M., 1977, Lat. 40°N Fault Zone, Pennsylvania: A New Interpretation: Geology, Vol. 5, p. 719-723.

Sbar, M. L., and Sykes, L. R., 1973, Contemporary Compressive Stress and Seismicity in Eastern North America: an example of Intraplate Tectonics: Geol. Soc. Am. Bull., Vol. 84, p. 1861-1882.

Sundheimer, Glen, 1979, "Isotime Structural Map: Top of the Basement, Cottageville Field, West Virginia. Copy in Proceedings, Unconventional Gas Recovery Symposium, May 16-18, 1982, Pittsburgh, Pennsylvania, Society of Petroleum Engineers and U.S. Department of Energy, p. 22.

Tetra Tech, Inc., 1980, "Producing Fields and Gas Shows in the Devonian Shale" Map, DOE Contract No. DE-AC21-79MC10389.

Thurlow, Weed and Associates, unpublished manuscript, "Devonian Shale Extraction Test Wells," DOE/METC Contract No. AC21-78MC08386.

Vickers, M. K., 1976, Marietta: unpublished manuscript, W. Va. Geol. Surv., 10 ms p.

Wagner, W. R., and Lytle, W. S., 1976, "Greater Pittsburgh Region Revised Surface Structure and Its Relation to Oil and Gas Fields": Pennsylvania Geol. Surv. Info. Circ. 80, 20 p.

Werner, E. B.,1977, "Application of Remote Sensing Studies to the Interpretation of Fracture Systems and Structural Styles in the Plateau Regions of Eastern Kentucky, Southwestern Virginia, and Southwestern West Virginia for Application to Fossil Fuel Extraction Processes," West Virginia University, Department of Geology and Geography, DOE Contract No. EY-76-S-21-8040.

Young, D. M., 1957, Deep Drilling Through Cumberland Overthrust Block in Southwest West Virginia: Am. Assoc. Petrol. Geol. Bull, Vol. 41, p. 2567-2573.

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